AN EVALUATION OF THE STATUS OF MYOTINE BATS IN THE PROPOSED MERAMEC PARK LAKE AND UNION LAKE PROJECT AREAS, MISSOURI

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AD A115957

PREPARED BY

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FOR

THE U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
210 N. 12TH ST., ST. LOUIS, MO 63101
CONTRACT NO. DACW43-76-C-0026

IN COOPERATION WITH

THE MISSOURI DEPARTMENT OF CONSERVATION
2901 NORTH TEN MILE DRIVE
JEFFERSON CITY, MO 65101

AND

THE U. S. FISH AND WILDLIFE SERVICE
FEDERAL BUILDING, ROOM 1748
601 EAST 12TH ST.
KANSAS CITY, MO 64106

FEBRUARY 1977

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. A115 957	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Evaluation of the States of Myotine Bats In the Proposed Meramec Park Lake and Union Lake Project Areas, Missouri		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard L. LaVal, Richard L. Clawson William Caire, Lloyd R. Wingate, Margaret L. LaVal		8. CONTRACT OR GRANT NUMBER(s) DACW43-76-C-0026
9. PERFORMING ORGANIZATION NAME AND ADDRESS The School of Forestry, Fisheries and Wildlife University of Missouri Columbia, Missouri.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis 210 Tucker Blvd., North St. Louis, MO 63101		12. REPORT DATE 3 Dec 1976
		13. NUMBER OF PAGES 145
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An eighteen-month field study of the endangered species Myotis sodalis (Indiana bat) and Myotis grisescens (gray bat) in the Meramec River Basin of eastern Missouri was carried out to determine: 1) numbers and locations of populations of the endangered bats in the Meramec Basin, 2) the seriousness of the impact of the proposed Meramec Park Lake and Union Lake on the bats, and 3) means by which projected negative impacts may be eliminated or reduced.

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Significant populations of M. sodalis (ca. 100,000) and M. grisescens (ca. 50,000) still exist in the area containing and adjoining the proposed lakes. Of 19 caves judged to be important to the bats, four will be destroyed by the lakes and eight seriously impacted. A maximum of 177 km of M. grisescens foraging habitat (streams) will be destroyed, as will much of the flood plain and hillside forest used by M. sodalis. Caves can be at least partially protected by gates and fences, and wise habitat preservation and management can help preserve foraging areas. Caves formerly used by the endangered bats can be restored to their use. However, even though protection ad wise management can at least partially offset the serious impacts of the lakes, certain serious impacts will remain. We believe that if all of these potential impacts are to be avoided, the only just solution is a decision not to build the lakes.

AN EVALUATION OF THE STATUS OF MYOTINE BATS IN THE PROPOSED MERAMEC PARK LAKE AND UNION LAKE PROJECT AREAS, MISSOURI

Final Report

by

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31 December 1976

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Abstract

An eighteen-month field study of the endangered species *Myotis sodalis* (Indiana bat) and *Myotis grisescens* (gray bat) in the Meramec River Basin of eastern Missouri was carried out to determine: 1) numbers and locations of populations of the endangered bats in the Meramec Basin, 2) the seriousness of the impact of the proposed Meramec Park Lake and Union Lake on the bats, and 3) means by which projected negative impacts may be eliminated or reduced.

Significant populations of *M. sodalis* (*ca.* 100,000) and *M. grisescens* (*ca.* 50,000) still exist in the area containing and adjoining the proposed lakes. Of 19 caves judged to be important to the bats, four will be destroyed by the lakes and eight seriously impacted. A maximum of 177 km of *M. grisescens* foraging habitat (streams) will be destroyed, as will much of the flood plain and hillside forest used by *M. sodalis*. Caves can be at least partially protected by gates and fences, and wise habitat preservation and management can help preserve foraging areas. Caves formerly used by the endangered bats can be restored to their use. However, even though protection and wise management can at least partially offset the serious impacts of the lakes, certain serious impacts will remain. We believe that if all of these potential impacts are to be avoided, the only just solution is a decision not to build the lakes.

TABLE OF CONTENTS

CONTENTS (Cont'd)

LIST OF TABLES

TABLES (Cont'd)

TABLES (Cont'd)

LIST OF FIGURES

FIGURES (Cont'd)

AN EVALUATION OF THE STATUS OF MYOTINE BATS IN THE PROPOSED MERAMEC PARK LAKE AND UNION LAKE PROJECT AREAS, MISSOURI

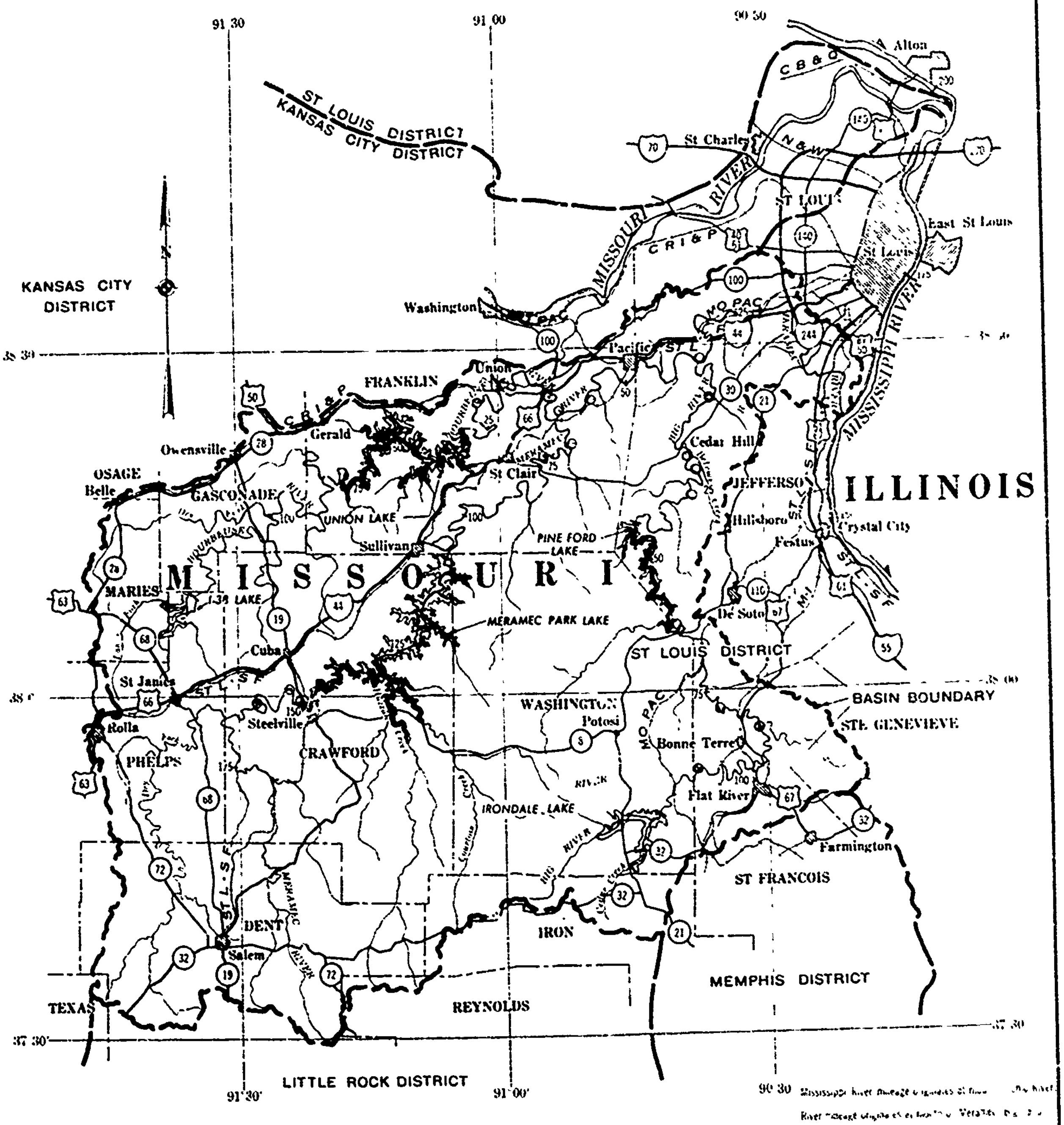
Final Report

When the final Environmental Impact Statement for the Meramec Park Lake was filed in August 1973, it stated that habitat of the endangered Indiana bat (Myotis sodalis) "... may be adversely affected." In December 1973 Congress passed the Endangered Species Act of 1973, affording a substantial degree of protection to M. sodalis and other endangered species. During 1974 the Department of the Interior, and the Sierra Club (in a lawsuit) pointed out that the Corps of Engineers might be in violation of the Endangered Species Act if the Meramec Park Lake is constructed. The desirability of a cooperative effort between the U.S. Fish and Wildlife Service and the Army Corps of Engineers to study the problem was discussed, and preliminary surveys of bat populations in the area were made. Finally, an agreement was reached whereby the University of Missouri would conduct an 18-month study of the status and ecology of all bats of the genus Myotis in the Meramec Park Lake area, to be sponsored jointly by the Corps of Engineers, Fish and Wildlife Service, and the Missouri Department of Conservation. The study was begun in July 1975. In 1976 the gray bat (Myotis grisescens) was added to the endangered species list, and thus became a crucial issue in the study, because of its large population in the Meramec Park Lake area.

DESCRIPTION OF THE STUDY AREA

The study area included that portion of the Meramec River drainage located in Franklin, Crawford, and Washington counties, Missouri, as well as a small portion of northern Dent County (see Fig. 1). Also included was the drainage of the Bourbeuse River in Franklin County. Studies were conducted at caves that are, for the most part, located near permanent streams and rivers. Additional investigations were made of foraging activities of bats over and near the streams and rivers themselves. The study concentrated on the Meramec River and its drainage because construction had already begun on Meramec Park Lake.

At least 225 caves are located in bluffs, steep hillsides, and sinkholes along the Meramec and its tributaries in the three-county area. This figure is based on records and publications of the Missouri Speleological Survey, and on interviews with members of that group, as well as local residents, plus our own investigations. In contrast, only a handful of small caves have been located near the Bourbeuse. These caves offer a wide variety of spatial and microhabitat conditions to bats and other cavernicolous organisms. However, human activities have closed or rendered many of them unsuitable, including four of the largest caves in the area.



LEGEND

District Boundary

Angler - Use Site

Fig. 1

FLOOD CONTROL PROJECT
MERAMEC RIVER
BASIN

U S ARMY ENGINEER DISTRICT, ST LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
JUNE 30, 197?

Table 1 contains a summary of pertinent information on caves visited since the initiation of the study. Included for comparative purposes are caves of little or no importance to myotine bats. Caves that are or have been of significance to bats are listed using the numerical designations of the U.S. Fish and Wildlife Service confidential list. Other caves are listed by the numbers assigned to them by the Missouri Speleological Survey; these numbers are preceded by letters - C for Crawford County; F for Franklin County; W for Washington County. Entrance elevations were estimated from topographical maps. The entrance elevations of caves 021, 022, 023, 030, 039, and 044 were determined by an Army Corps of Engineers survey. If the cave lies within the normal pool elevation (675 ft) the figure is suffixed by an "N"; if in the flood pool elevation (709 ft), by an "F". Entrance width (EW) and entrance height (EH) were obtained from the Missouri Speleological Survey Cave Catalog or estimated by us. Relative lengths were mostly estimated, as very few of these caves have been mapped. A room is defined as any significant enlargement of a cave passageway, usually with a ceiling height well in excess of head height. Formations (speleothems) include flowstone, stalagmites, stalactites, helictites, columns, onyx, etc. Major vandalism is the destruction or defacement of numerous formations. Virtually all caves in the area have suffered some vandalism. Visitation was judged to be light, moderate, or heavy

Table 1. Pertinent data on caves in the Meramec Park Lake area.

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
001	Sink	780	7	4	Med.	Yes	Yes	No	Str.	Mod.	B, S
002	Sink	710	15	9	Med.	Yes	Yes	No	Str.	Mod.	B, F
003	Tunnel	620	25	25	Med.	Yes	Yes	No	Str.	Heavy	B
004	Tunnel	710	2 Ent's		Short	No	No	No	Dry	Mod.	
005	Tunnel	700	Gated		Long	Yes	Yes	No	Str.		B, S, I, F
006	Tunnel	580	Gated		Long	Yes	Yes	No	Str.		B, S, I, F
007	Bluff	640	8	5	Short	Yes	No	No	Dry	Mod.	B
008	Tunnel	600	Gated		Long	Yes	Yes	No	Str.		B, S, I, F
009	Sink	680	10	6	Short	Yes	Yes	No	Dry	Light	B, S
010	Seep	600			Med.	No	No	No	Str.	Light	
011	Sink	780	15	6	Med.				Str.		B
012	Sink	650N			Med.				Str.		
013	Tunnel	640N	15	25	Long	Yes	Yes	No	Str.	Heavy	B, S, I, F

N Within normal pool
F Within flood pool
Type Type of entrance
Elev. Elevation (in.ft.)
EW Entrance width(in.ft.)
EH Entrance height(in.ft.)
Sink = Entrance through sinkhole
Tunnel = Walk-in type entrance
Bluff = Entrance in bluff wall
Seep = Low entrance with emerging spring

Length Short: 20-100'
Med.: 100-500'
Long: 500+'
Forma. Formations (speleothems) present
Water Str.(stream), lake or dry

Visitation Light, moderate or heavy (rough est.)
Organisms present B: Bats
S: Salamanders
I: macroscopic Invertebrates
F: Frogs

Table 1. (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
014	Tunnel	640^{N}	20	20							
015	Bluff	600^{N}	50	100	Long	No	Yes	No	Str.	Heavy	B, S, I, F
016	Tunnel	630	10	6	Short	No	No	No	Dry	Heavy	B
017	Sink	800	6	4	Long	Yes	Yes	No	Lake	Heavy	B
018	Tunnel	720	3	3	Short	No	No	No	Dry	Mod.	
019	Tunnel	700	3	3	Med.	No	No	No	Dry	Mod.	
020	Sink	700^{F}	4	3	Long	Yes	Yes	No	Str.	Mod.	B
021	Tunnel	720	Gated(50x8)		Long	Yes	Yes	Yes	Lake	Heavy	B, S, I, F
022	Sink	689^{F}	12	4	Long	Yes	Yes	No	Lake	Heavy	B, S, I
023	Bluff	656^{N}	25	21	Long	Yes	Yes	No	Lake	Heavy	B
024	Tunnel	660^{N}	30	7	Long	Yes	Yes	No	Str.	Heavy	B
025	Bluff	640^{N}	20	9	Short	No	No	No	Str.	Heavy	
026	Bluff	720	15	20	Med.	No	Yes	No	Str.	Heavy	B
027	Bluff	690^{F}	25	25	Med.	Yes	Yes	Yes	Str.	Heavy	
028	Tunnel	680^{F}	25	15	Med.	No	No	No	Str.	Mod.	B
029	Tunnel	720	20	12	Long	Yes	Yes	No	Str.	Heavy	B, S, I
030	Bluff	637^{N}	40	20	Long	Yes	Yes	No	Str.	Heavy	B, S, I, F
031	Sink	860	10	7	Long	Yes	Yes	No	Str.	Light	B, I
032	Tunnel	820	35	9	Long	Yes	Yes	No	Str.	Light	B, S, I, F

Table 1. (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Form.	Major Vandalism	Water	Visitation	Organisms Present
034	Bluff	600	15	20	Med.	Yes	No	No	Str.	Heavy	B
035	Bluff	710	6	2	Med.	Yes	Yes	No	Lake	Mod.	B, S
036	Bluff	920	10	15	Med.	Yes	Yes	No	Str.	Mod.	B
037	Bluff	690[F]	42	9	Long	Yes	Yes	No	Str.	Mod.	B, I, F
038	Sink	810	3	3	Med.	Yes	Yes	No	Str.	Mod.	B
039	Bluff	683[F]	32	11	Med.	Yes	Yes	No	Lake	Mod.	B
040	Bluff	920	12	20	Med.	No	Yes	No	Str.	Heavy	B
041	Tunnel	700[F]	75	17	Short	No	No	No	Str.	Heavy	B
042	Sink	850	7	4	Long	Yes	Yes	No	Str.	Light	B, S
044	Tunnel	693[F]	4	3	Long	Yes	No	No	Str.	Light	B, S, F
045	Tunnel	760	2	2	Long	Yes	Yes	No	Str.	Light	B, S, I, F
048	Bluff	530	50	5	Med.	No	No	No	Dry	Heavy	B
049	Bluff	550	4	4	Long	Yes	No	No	Str.	Heavy	B
050	Bluff		25	8	Med.	Yes	Yes	No	Str.	Mod.	B
051	Bluff		25	8	Med.	Yes	Yes	No	Str.	Mod.	B
052	Bluff		12	15	Short	No	No	No	Str.	Mod.	B
054	Bluff	600	30	10	Short	No	No	No	Str.	Heavy	B

Table 1 . (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
C 1	Bluff	650^N	Closed		Long	Yes	Yes	No	Str.	Heavy	B
C 11	Bluff	660^N	15	10	Short	No	No	No	Dry	Mod.	B
C 15	Tunnel	640^N	25	15	Med.	Yes	No	No	Dry	Mod.	B
C 16	Tunnel	640^N	40	18	Med.	No	No	No	Dry	Mod.	B
C 17	Sink	670^N	3	2	Med.	Yes	No	No	Str.	Mod.	B
C 18	Sink	780	60	5	Med.	No	Yes	Yes	Dry	Mod.	B
C 23	Sink	800	2	2	Long	Yes	Yes	No	Str,	Light	B, F
C 24	Sink	760	15	3	Med.	Yes	Yes	No	Str.	Mod.	B
C 28	Bluff	680^F	30	15	Med.	Yes	No	No	Str.	Heavy	B
C 32	Tunnel	760	25	15	Short	No	No	No	Dry	Mod.	
C 35	Bluff	660^N	3	3	Short	No	No	No	Dry	Mod.	
C 39	Bluff	700^F	15	9	Short	No	No	No	Str.	Heavy	
C 43	Bluff	820	30	4	Short	No	No	No	Dry	Heavy	
C 45	Tunnel	700^F	25	3	Med.	No	No	No	Dry	Mod.	
C 47	Tunnel	760	4	3	Med.	No	No	No	Dry	Mod.	
C 51	Bluff	640^N			Short	No	No	No	Dry	Mod.	
C 52	Bluff	640^N			Short	No	No	No	Dry	Mod.	
C 55	Bluff	760	11	5	Short	No	No	No	Dry	Mod.	

Table 1 . (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
C 56	Tunnel	740	2	2	Med.	No	No	No	Dry	Mod.	
C 58	Sink	740	40	8	Med.	No	No	No	Str.	Mod.	B
C 59	Tunnel	720			Long	Yes	Yes	No	Str.	Mod.	B
C 60	Tunnel	720	6	5	Short	No	No	No	Str.	Mod.	
C 61	Bluff	660^N	3	1	Short	No	No	No	Dry	Mod.	
C 62	Tunnel	800	3	2	Long	No	No	No	Str.	Light	
C 64	Bluff	620	25	35	Med.	No	No	No	Str.	Mod.	B
C 66	Tunnel	760	25	7	Med.	No	No	No	Dry	Light	B
C 71	Bluff	700^F			Short	No	No	No	Dry	Mod.	
C 72	Bluff	750			Short	No	No	No	Dry	Mod.	
C 74	Bluff	620^N			Short	No	No	No	Dry	Heavy	
C 76	Sink	800	2	2	Long	Yes	Yes	No	Str.	Mod.	B
C 78	Bluff	600^N	5	4	Med.	No	No	No	Str.	Heavy	
C 84	Bluff	680^F	3	2	Short	No	No	No	Dry	Mod.	
C 85	Sink	760	6	3	Long	Yes	Yes	No	Str.	Light	B
C 87	Bluff	660^N	30	15	Med.	No	No	No	Str.	Mod.	
C 88	Sink	740			Med.	No	No	No	Str.	Light	S
C 91	Bluff	700^F			Med.	No	No	No	Dry	Mod.	
C 95	Bluff	680^F	14	4	Short	No	No	No	Dry	Mod.	

Table 1. (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
C 96	Bluff	700^{F}			Short	No	No	No	Dry	Mod.	
C102	Bluff	600^{N}	4	4	Short	No	No	No	Dry	Mod.	
C104	Bluff	620^{N}	20	45	Med.	No	No	No	Dry	Heavy	B
C111	Sink	900	5	3	Long	Yes	Yes	No	Str.	Light	B
C114	Sink	740	25	8	Med.	Yes	Yes	No	Str.	Mod.	B
C116	Sink	780	10	4	Long	Yes	Yes	Yes	Str.	Mod.	B
C118	Bluff	640^{N}	3 Ent's		Short	No	No	No	Dry	Mod.	
C119	Bluff	640^{N}	10	10	Short	No	No	No	Dry	Mod.	
C121	Bluff	690^{F}			Short	No	No	No	Dry	Mod.	
C123	Tunnel	700^{F}	20	40	Med.	No	No	No	Str.	Mod.	B
C125	Bluff	680^{F}	4	4	Med.	No	No	No	Str.	Mod.	
C127	Tunnel	745	50	9	Med.	No	Yes	Yes	Str.	Mod.	R, S
C129	Bluff	640^{N}	4	3	Short	No	No	No	Dry	Mod.	
C130	Bluff	620^{N}	3	3	Long	No	No	No	Dry	Mod.	B
C136	Sink	930	3	8	Long	Yes	Yes	No	Str.	Light	B
C138	Bluff	620^{N}			Short	No	No	No	Dry	Mod.	
C143	Bluff	660^{N}	25	12	Short	No	No	No	Dry	Mod.	
F 1	Bluff	570	30	12	Long	Yes	Yes	Yes	Str.	Heavy	B
F 11	Bluff	630	20	8	Short	No	No	No	Dry	Heavy	

Table [illegible]. (Cont'd)

Cave	Type	Elev.	EW	EH	Length	Rooms	Forma.	Major Vandalism	Water	Visitation	Organisms Present
F 15	Tunnel	800	2 Ent's		Long	Yes	Yes	Yes	Str.	Heavy	B
F 17	Bluff	610	60	20	Short	No	No	No	Dry	Heavy	
F 18	Tunnel	600	12	7	Short	No	No	No	Dry	Heavy	
F 19	Bluff	620	20	12	Short	No	No	No	Dry	Heavy	
F 35	Bluff	560	35	10	Med.	Yes	No	No	Str.	Mod.	B
F 38	Bluff	620			Short	No	No	No	Dry	Mod.	
F 42	Tunnel*	560^{N}	60	10	Short	No	No	No	Dry	Mod.	
F 43	Bluff	640^{F}			Short	No	No	No	Dry	Mod.	
F 57	Bluff*	550	10	15	Short	No	No	No	Dry	Mod.	
F 58	Tunnel*	740	15	4	Short	No	No	No	Dry	Mod.	
F [illegible]	Tunnel*	650^{F}	3 Ent's		Short	No	No	No	Dry	Mod.	
F [illegible]	Tunnel*	580^{N}	10	25	Med.	No	No	No	Str.	Mod.	
W 5	Bluff	840	50	10	Long	Yes	Yes	No	Str.	Mod.	B
W 8	Tunnel	780	45	12	Short	No	No	No	Dry	Mod.	
W 9	Bluff	860	25	10	Short	No	No	No	Dry	Mod.	
W 12	Pit	800	2 Ent's		Med.	No	No	No	Str.	Mod.	
W 42	Tunnel	850	6	3	Long	Yes	Yes	No	Str.	Light	B

* Union Lake area

by observation of litter, footprints, vandalism, and other signs of human activity.

All caves in the area contain some living organisms. No attempt was made to census cave life. Our field notes, however, suggest that certain taxa of organisms are more abundant in some caves than in others, as would be predicted from the variation in microhabitat among the caves. The major groups of animals that appeared to be more common to us are listed in the last column of Table 1.

The following caves have not been visited by us, but information was obtained about them from various sources, mostly from persons who had personally explored the caves. From the information thereby made available to us, we judge that these caves cannot be considered as suitable habitat for myotine bats. The Missouri Speleological Survey numbers follow, grouped by counties. Crawford: 02, 09, 12, 13, 14, 20, 22, 26, 34, 41, 42, 46, 48, 53, 54, 57, 63, 65, 68, 70, 75, 77, 79, 81, 89, 90, 92, 94, 97, 100, 101, 103, 105, 106, 107, 109, 110, 112, 113, 115, 117, 120, 122, 124, 126, 128, 132, 134, 137, 140, 141, 142, 143, 144; Franklin: 08, 10, 20, 25, 26, 31, 32, 33, 37, 40, 41, 44, 51, 52, 53, 61, 62; Washington: 02, 03, 04, 10, 11, 14, 15, 16, 17, 19, 21, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 43, 44.

In the overall Meramec Basin area, the amount of forest cover is 59 percent (anon.,1973). However, in the vicinity of the proposed Meramec Park Lake, the percentage is much higher, exceeding 90 percent in some areas. The upland forest is predominantly oak-hickory in various stages of succession, from abandoned fields to mature forest, thereby providing a wide variety of foraging habitats for bats. Riparian and floodplain forests are restricted to the narrow valleys of permanent streams and rivers. Approximately 25 percent of the floodplain of the Meramec and its major tributaries remains in forest, as estimated from aerial photographs; the remainder is devoted to agriculture, mainly pasture. Hillsides and ridges support a dense growth of Ozark Oak-Hickory forest (*Quercus-Carya*), whereas floodplain and riparian forests are characterized by mixed hardwoods, especially sycamore (*Platanus occidentalis*), willows (*Salix* sp.), cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), sugar maple (*Acer saccharum*), silver maple (*Acer saccharinum*), and bitternut hickory (*Carya cordiformis*). Forest cover in various stages of succession exceeds 90 percent, except that only about 25 percent of the narrow floodplain remains in forest, the remainder having been converted to agricultural uses. Even where floodplain forest has been cleared, riparian forest strips remain. The Meramec River and its tributaries in the study area are clear, shallow, swiftly-flowing streams with gravel bottoms. Areas of fast water, locally called "riffles", are typically separated by relatively quiet pools. It is over these pools where bat activity seemed to be concentrated.

An abundance of additional data on forests, agriculture, population, fauna and flora, geology, etc. are contained in the Final Environmental Statement (anon., 1973).

In this study, data were gathered from caves along the Meramec and its tributaries from Twin Springs (just downstream from Meramec Caverns) to the Highway 19 bridge in Dent County, a distance of 97 river miles (155 km), or 45 airline miles (72 km), and upstream on the Courtois and Huzzah creeks as far as Berryman and Davisville, respectively. These towns are located 14 and 23 river miles (22.4 km and 36.8 km), respectively, upstream from the confluence of the Huzzah with the Meramec. The only important bat caves along the Bourbeuse are located 8 river miles (12.8 km), or 2 airline miles (3.2 km), downstream from the site of the proposed dam.

Studies of foraging habitat and behavior were carried out at numerous sites along the Meramec, Courtois, Huzzah, and four other permanent streams tributary to the Meramec. However, only three nights of netting were performed on three streams flowing into the Bourbeuse. Therefore, generalizations based on Meramec Park Lake data may not necessarily apply to Union Lake areas. All sites were characterized by clear, fast-flowing water interspersed with pools, and dense riparian forest. Figures 1 and 2 show locations of the lakes, netting sites, and areas where

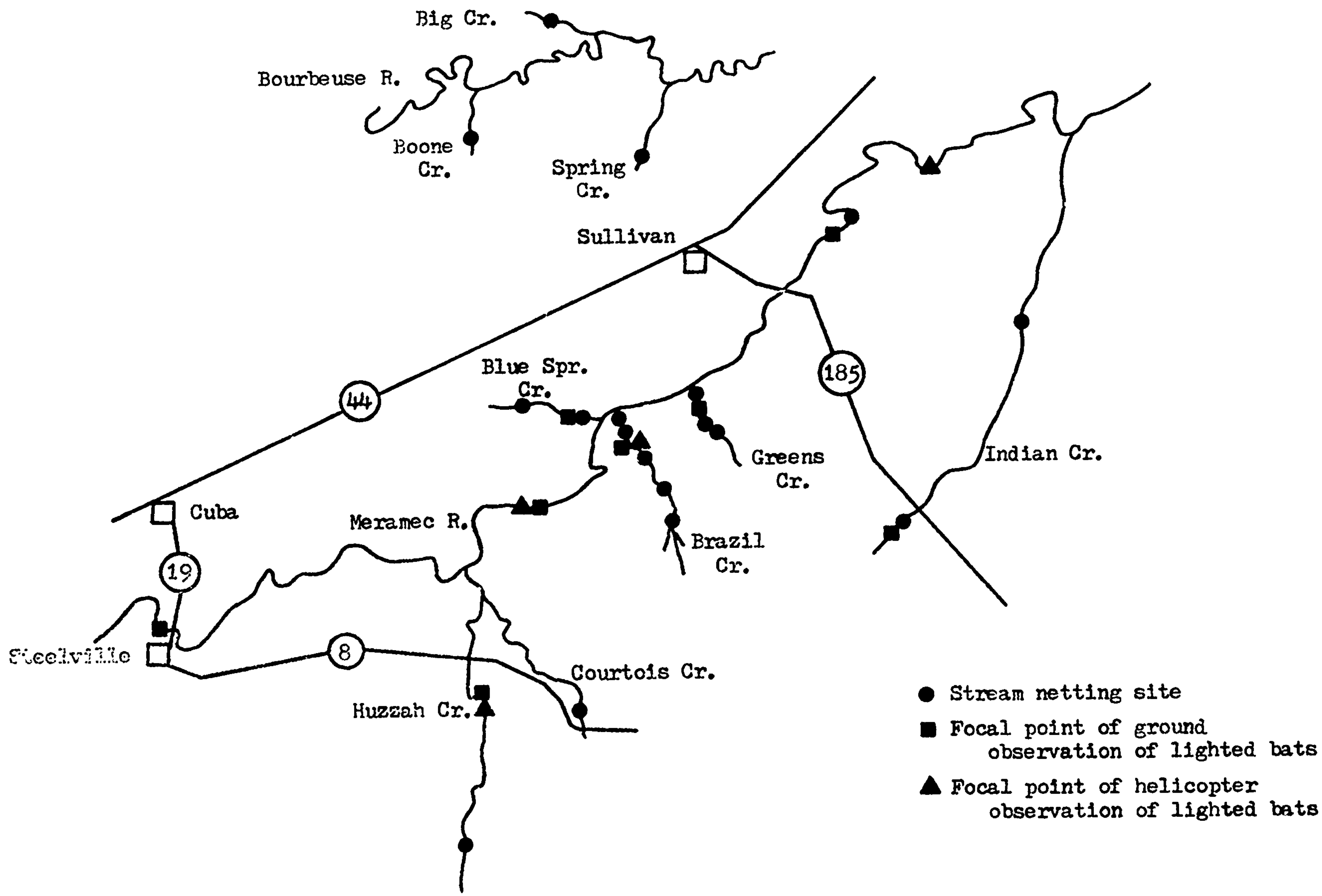


Fig. 2. Netting and light tracking sites in the Meramec Basin, 1976.

light-tracking activities were carried out.

For the purposes of this report, myotine bats are those species belonging to the genus Myotis. The word "myotine" is not established in the literature of mammalogy and is used here only because of previous application in communications and reports to this project. Only four species of myotine bats were encountered during the study (M. sodalis, M. grisescens, M. keenii and M. lucifugus).

MATERIALS AND METHODS

During the course of this study (1 July 1975 - 31 December 1976), the vast majority of bats handled were captured in harp traps (Tuttle, 1974) placed at cave entrances, or in mist nets placed across streams. On a number of occasions nets over streams were supplemented with traps also placed over streams. Hibernating bats were normally not disturbed beyond estimating their numbers and recording presence of plastic bands (if band numbers could be read without handling the bats, this was done). Active summer clusters of M. grisescens were sometimes caught in a hand net, although such activities were never carried out in maternity caves. During the maternity season, maternity caves of M. grisescens were visited only at night, following the exodus of adult females. Bats counted or estimated while roosting, without being touched, are listed in tables as "observed", while those actually grasped and examined are shown as "handled".

Numerous bats were counted or estimated at all times of the year, but especially during hibernation, by making regular visits to important caves. When large clusters were found, an estimate of the area of the cluster was recorded. At intervals, clusters of known area were counted. A photograph incorporating an ordinary metal ruler superimposed on a portion of a large cluster of *M. sodalis* provided a means whereby our estimates could be verified. The photograph shows over 300 *M. sodalis* in one square foot. Estimated numbers of clustering *M. grisescens* follow estimates given by Tuttle (1975) as well as our own counts.

Censuses of hibernating bats were made at preselected intervals, originally four-week but later changed to six-week. All five *M. sodalis* caves were censused within a four-day period at each census. Trapping at *M. grisescens* caves was concentrated during periods when we believed bats to be present. Daytime checks were made at other times of the year to determine the presence of bats. We recognize the fact that, because all counts in a given month were not made on the same day, some bats may have moved to a different cave and thus may have been counted twice. Conversely, other bats may have moved just before the counts were made. We feel that these two effects tend to cancel each other.

Subject to availability of bands, bats were banded (right forearm for males, left for females) with numbered plastic bands obtained from A. C. Hughes, Hampton Hill, England. A different color was used for each species. A two-color unnumbered band was affixed to the opposite wing to signify the cave of banding.

Totals of 6763 M. sodalis, 4988 M. grisescens, 945 M. keenii, and 1487 M. lucifugus were banded.

Environmental readings were recorded with a Schultheis quick-reading mercury thermometer (air temperature, taken about 1m above the floor under clusters); with a Wahl Heat Spy Digital Infrared thermometer, model DHS-14 (substrate and cluster temperatures); and a Bendix Psychron motor-driven psychrometer, model 566-2 (relative humidity was taken in same spot as air temperature).

Ultrasonic bat sounds were monitored using a Son-Tector model 110M (Techsonics, Inc.) ultrasonic detector. Lighted foraging bats were timed with a Siliconix ET 105 electronic digital stopwatch. Cyalume chemiluminescent chemicals used in light-tracking were manufactured by American Cyanamid Corporation. Four walkie-talkies (models TRC-99C and TRC-35C) were supplied by Radio Shack Corporation, as was the cassette tape recorder, model CTR-34B. A Paulin altimeter, model M-1-6, was used to survey entrance elevations of certain caves, although most of these were later verified by a Corps of Engineers survey team. Certain observations were made using a Javelin model 220 night viewing device. Our normal light sources were Mine Safety Appliances model ML-2 miners lamps and Ray-O-Vac Sportmans headlamps equipped with Globe Gel-Cell rechargeable batteries. Mist nets were mostly of the monofilament type supplied by Bleitz Wildlife Foundation. Bats were weighed with Pesola spring scales (Oskar Lüdi and Company, Basel, Switzerland).

Stream netting activities were confined to the period 21 May through 14 September 1976. From six to ten nets were erected at stream level on 23 nights, mostly during the dark of the moon. Most of this netting was carried out over small tributary streams, but on one night the Meramec River itself was netted as were the two major tributaries, the Courtois and Huzzah. Nets were usually tended constantly by four persons from dusk to about 2400 hours (but sometimes as late as 0300).

Cave trapping activities extended from 12 August through 7 November 1975, and from 1 March through 13 October 1976. Trapping activities for M. sodalis were concentrated during pre- and post-hibernation movements. However, cave 029 was trapped throughout the summer as well. Trapping for M. grisescens was continued throughout the trapping months listed above. A total of 83 trap-nights was recorded for all efforts to catch all species (Table 2).

Because bats are nocturnal, direct observation of foraging activities is difficult, although inferences relating to foraging behavior can be (and have been) made from other kinds of data. In this study we decided to actually watch bats foraging by affixing lights to them. Glass spheres or gelatin capsules containing Cyalume high intensity chemiluminescent liquid (see Buchler, 1976) were glued onto 400 bats. The fluid-filled spheres weighed up to 0.75g, whereas the capsules only weighed 0.23g

Table 2. Type of sampling technique and number of times employed per month, 1975-1976.

		Sampling Technique				
					Light tracking	
Month	Year	Cave trapping	Hand net	Stream netting	Ground	Helicopter
Aug	1975	9	4	0	0	0
Sept	"	9	2	0	0	0
Oct	"	9	4	0	0	0
Nov	"	3	1	0	0	0
Mar	1976	1	6	0	0	0
Apr	"	8	6	0	4	0
May	"	8	7	4	8	0
June	"	5	4	7	3	1
July	"	9	7	6	0	1
Aug	"	10	3	4	1	1
Sept	"	9	2	2	0	1
Oct	"	3	2	0	0	0
Totals		83	48	23	16	4

when full. The lights were glued either ventrally for ground observation or dorsally for observation from the air. Additional details are contained in LaVal, et al. (1976).

Two hundred sixteen ventrally lighted bats were released singly at normal exit times from roost caves, or, in a limited number of cases, released where netted or trapped over streams. Normally the next individual was not released until the previously released bat was lost from view. Observations were made by four individuals with walkie-talkies, spaced along a one to two mile section of the stream adjacent to the roost cave. Observations were recorded by a cassette tape recorder attached directly to one of the walkie-talkies.

One hundred eighty eight dorsally lighted bats were released in rapid succession from caves at normal exit times. Observations were made by two of us from a helicopter flying at an altitude of about 150 m and a speed of 60 knots (111 km/hr.). We were able to hover or fly tight circles when necessary. Observations could be made only when the moon was between one quarter and one half phase, which allowed us to see bats fairly easily while providing just enough illumination for the pilot to navigate. Cloudy and cold weather reduced the number of nights available to us, so that the helicopter was used for light tracking for four nights only. Furthermore, the helicopter carried only enough fuel for one hour of continuous observation.

As it turned out, this was usually sufficient, as the chemical lights were fading and bats were returning to caves within an hour of release. There seemed to be no differences in observed behavior from the air, as opposed to the ground, that might be attributed to helicopter noise or prop-wash.

Cave numbers given in this report are those of the confidential U.S. Fish and Wildlife Service list. A few caves not represented on that list are indicated by MSS (Missouri Speleological Survey) numbers, which are preceded by letters indicating county.

RESULTS AND DISCUSSION

The results and discussion below follow the outline as given in Appendix A, "Scope of Work" of Contract DACW-76-C-0026.

Phases I and IV

Spring-Summer Population and Habitat Analysis

According to the Contract, this phase was to have covered the period 1 May-30 August. However, the hibernation period terminates during March and April for almost all bats, so that spring-summer behavior patterns are initiated in March and April. By late July, maternity colonies (at least in *M. grisescens*) have dispersed and swarming has begun. Therefore, only the data for April through July are judged to be appropriate for the Phase I and IV discussion. In the discussion that follows, combined Phase I and Phase IV data will be referred to as Phase I.

Reproduction

Myotis sodalis, *M. keenii* and *M. lucifugus*

These species are present throughout the year in varying numbers. *Myotis sodalis* males were resident in significant numbers during Phase I, but females were largely absent (Table 1). During June, when parturition and lactation occur (Humphrey, et al., 1976) no females were captured. No juveniles were encountered during the period.

Populations of M. lucifugus and M. keenii during Phase I were represented mostly by males, with only three and four females, respectively, of the two species captured during the parturition-lactation period of June. All of these females were non-reproductive. Only one M. lucifugus juvenile was encountered, but eight M. keenii juveniles were caught, including some barely old enough to fly (Table 3).

No other data were obtained on reproductive activities of these three species during Phase I. Based on these observations, it would appear that reproductively-active female M. sodalis, M. lucifugus, and M. keenii were absent from the study area during June and early July. The possibility that nursery colonies exist in the area cannot be discounted. However, through use of our sampling techniques (netting and trapping), we should have encountered pregnant and lactating females if they were present (see Table 2). Mist-netting over streams and at caves in areas where these three species are thought to bear their young has produced reproductive females, for example, in Indiana (Whitaker and Mumford, 1972; Cope, et al., 1974).

On the other hand, if maternity colonies were widely spaced, there is a possibility that our nets were never placed within foraging ranges of bats in these colonies. This latter hypothesis

Table 3. *Myotis* captured in the study area, 15 April 1976 through 31 July 1976.

		Adults ♂	Adults ♀	Juveniles ♂	Juveniles ♀	Total	Percent of grand total
M. sodalis	April	221	4	0	0	225	
	May	189	3	0	0	192	
	June	167	0	0	0	167	
	July	637	27	0	0	664	
						1248	15.0%
M. grisescens	April	613	728	0	0	1341	
	May	554	660	0	0	1214	
	June	743	219	95	112	1169	
	July	413	814	408	380	2015	
						5739	69.0%
M. lucifugus	April	21	34	0	0	55	
	May	82	53	0	0	135	
	June	31	3	0	0	34	
	July	142	18	0	1	161	
						385	4.6%
M. keenii	April	25	3	0	0	28	
	May	51	5	0	0	56	
	June	676	4	0	0	680	
	July	140	28	3	5	176	
						940	11.3%
Total						8312	

might apply best to M. keenii, as juveniles were netted at scattered intervals during July.

Though males and a few females of these three species were routinely trapped at caves during Phase I, they were only rarely found roosting in caves, except during early April when a few were still in hibernation. Because nursery roosts of these species occupy buildings and trees (Barbour and Davis, 1969; Humphrey, et al., 1976; Humphrey and Cope, 1976) we did not expect to find females and juveniles in caves.

Myotis grisescens

Myotis grisescens, on the other hand, raise their young at several maternity caves in the study area. Large numbers of bats of both sexes, as well as juveniles, were captured in the study area during June and July (Table 3). Nearly 15000 non-volant young bats were observed in four caves at night when adults were absent (Table 4), and we believe our estimate is conservative. Because M. grisescens bear single young (Barbour and Davis, 1969), one would predict that at least 15000 adult females (excluding yearlings) would be present equalling 30000 females and young. If males and yearling females were also present, as is the case, a population for the study area well in excess of 30000 (for June-July) would be anticipated. Actual roost estimates were 34000+ (June) and 37000+ (July) (see Table 5). If the uncounted bats represented by the asterisk and

Table 4. Highest number of non-volant young *Myotis grisescens* observed in caves during June-July 1976.

Cave number	Number of bats
036	9000
048	1800
054	3600
039	158
Total	14558

Table 5. **Estimated numbers of *Myotis grisescens* roosting at caves in the study area, April-July 1976.**

Cave number	April	May	June	July
009	15			225
017				225
021	1765			387
029	215	+	+	5012
030	187	3060	13	2700
032	305	452	16	
034	1350	34		85
035	700	100		130
036(M)	4855	9410	20000	18600
039	*	*	6783	*
044	1368			
048(M)	600		*	9600
049		1200		
054(M)	____	3000	7500	54@
Totals	11360	17256	34312	37018

+ Bats probably present; roost site not discovered until July.

* Bats present but no estimate made.

(M) Maternity cave.

@ Count made after maternity colony departed in mid-July.

plus marks on Table 5 in June had numbers equalling the July count for those two caves, then the total population recorded for July would have been between 45000 and 50000. We believe the actual maximum population in the study area may approach the latter figure.

At caves 036, 048, and 054 only juveniles and adult females were present during June and early July. The remaining caves were populated by males, with a few non-reproductive females intermixed. During April, May, and late July most caves were occupied by groups of mixed sexes, and, during late July, also of mixed ages.

The reproductive conditions of adult females between 18 May and 17 August are recorded in Table 6. At the beginning of this period virtually all adult non-yearling females were pregnant. Tuttle (_in litt_.) stated that yearling females are not pregnant their first year, and these undoubtedly account for most of the non-pregnant females and non-lactating females observed during May and June. However, in 1976, we captured six pregnant, lactating, or post-lactating females that had been banded as juveniles in 1975. The possibility exists that some or all of these individuals were improperly aged in 1975, but we doubt it. (Females were undoubtedly pregnant throughout April and May, but, as no dissections were performed, we were unable to record the initiation and progress of pregnancy.)

Table 6. Reproductive conditions of adult female *Myotis grisescens*, 1976.

Cave #	Date	N	Percent pregnant	Percent lactating	Percent non-reproductive	Percent post-lactating
T 039	18 May	42	76	0	24	0
T 030	19 May	103	92	0	8	0
H 034 H 035 H 054	20 May	133	99	0	1	0
T 030	3 June	49	57	14	28	0
T 054	1 July	186	0	50	3	47
T 054	14 July	100	0	20	2	78
H 035	5 Aug.	35	0	3	43	54
T 029	7 Aug.	53	0	0	75	25
T 030	17 Aug.	84	0	0	100	0

T = Trapped at cave entrance.

H = Caught with a hand net.

At the end of the period all females were non-reproductive. The reproductive chronology as it relates to juvenile bats is recorded in Table 7. The critical period during which adult females were nursing their young extended from at least 1 June to 5 August; Tuttle (*in litt.*) notes that births begin in late May. However, by late July most young had attained forearm lengths equal to the adults', and were foraging independently of their mothers, as far as we could determine. Only in October did male juveniles equal adult males in weight, although according to Tuttle (*in litt.*) adult males entering hibernation outweigh juvenile males. Females had already departed from the study area for the hibernacula by that time, and thus could not be weighed.

As far as we could determine, caves used by large numbers of *M. grisescens* in summer share only one physical trait: a ceiling dome whose temperature may be raised above ambient by metabolic heat (see discussion in Tuttle, 1975). Tuttle noted that such domes were characterized by relatively warm, stable temperatures even when bats were absent, by minimal air movement, and by roughness (which tends to impede air flow). These domes may be very large, in some cases the ceiling of an entire room, or small, one meter or less in diameter. Though a few of these caves are extensive in length, with large rooms, others are short (cave 054, for example, barely extends past the twilight

Table 7. Chronology of reproduction and growth of *Myotis grisescens*, 1976.

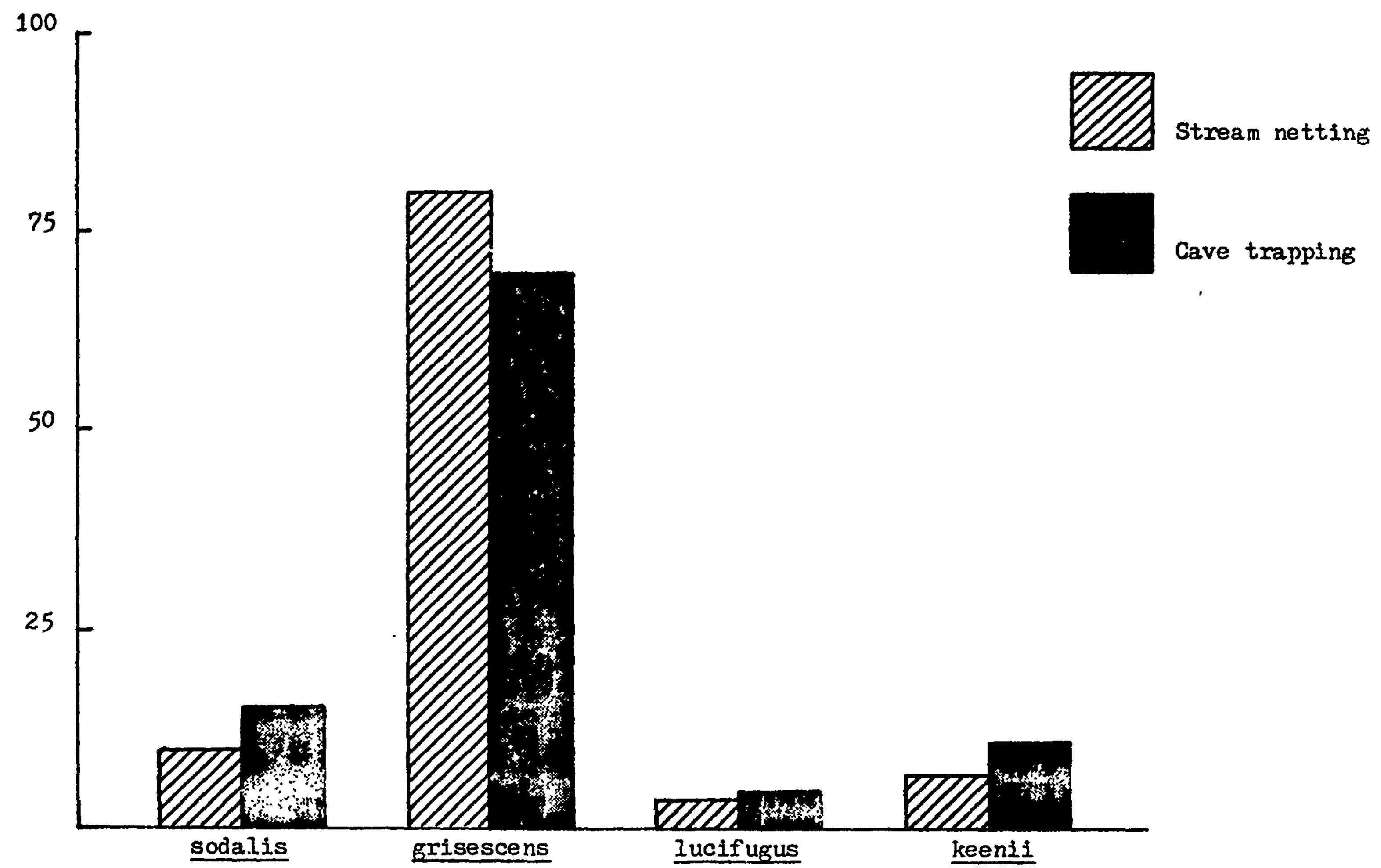
Date	Event
13 May	First palpable pregnancy observed.
1 June	First lactating female caught, first evidence of parturition.
18 June	First faltering flights of juveniles observed.
30 June	First date on which many young capable of sustained flight.
1 July	First juvenile reached mean adult forearm (FA) length.
3 July	Last newborn young observed, last evidence of parturition.
10 July	First juvenile flew from nursery site to another cave.
14 July	Mean juvenile FA length equaled mean adult FA length.
16 July	First juvenile netted while foraging.
5 Aug.	Last lactating female caught, last evidence of nursing.
14 Oct.	Mean juvenile male weight equaled mean adult male weight.

zone), and many are characterized by very small passages (as low as 30 cm) through which bats must pass (even though entrance size was normally quite large). Most M. grisescens caves are relatively warm (T_A = 13.8° to 24°C in July, $\bar{X}$= 16.9°C, adjacent to occupied roost sites), as opposed to caves used by M. sodalis as hibernacula (T_A= 11.8° to 13.4°C in July, $\bar{X}$= 12.8°C, adjacent to winter roost sites). In caves with a variety of temperatures, M. grisescens chose roosting sites in the warmer parts of the cave. Roosting sites may be in the twilight zone, or up to several thousand feet into the cave. Relative humidities adjacent to roost sites of M. grisescens (29 readings) varied from 73 to 94 percent ($\bar{X}$= 85.8 percent) for the April-July period. Tuttle (1975) reported a range of 85-100 percent for six maternity caves.

Relative Abundance

The relative numbers of the four species of Myotis shown in Fig. 3 primarily reflect numbers of bats entering caves at night, and are almost certainly not proportional to actual relative frequency of the four species. They do suggest, however, that sizable numbers of all these species remain in the study area during Phase I, especially in the case of M. keenii in June. Mist-netting and trapping over streams also provide a biased sample, due to differential vulnerability of the species to

Fig. 3. Relative proportions of four species of *Myotis* taken by two sampling techniques, 1976.



the capture technique, and due to differntial use of streams as flyways and foraging sites (see, for example, Kunz, 1973; Fleming, et al., 1972; LaVal, 1970). Nevertheless, relative numbers of bats captured in this manner (Table 8) probably provide a better measure of relative abundance than cave-trapped bats. M. grisescens was a close second in catch rate to Lasiurus borealis, a tree-roosting species, but roughly ten times as abundant as any of the other three species of Myotis, which ranked sixth, seventh, and ninth out of ten species of bats. Relative abundance as indicated by cave-trapping and stream-netting is compared in Fig. 3. Myotis lucifugus was caught in similar proportions using both techniques, but more M. grisescens were taken by stream-netting, while fewer M. sodalis and M. keenii were captured. These results are related to foraging behavior, as discussed below.

Flight Behavior and Foraging Habitat

Flight behavior of M. grisescens, M. sodalis, and M. keenii, based on observations from the ground, is summarized in Table 9.

Myotis grisescens usually forage over water and adjacent riparian vegetation. Foraging usually occurs below treetop height and sometimes as low as head height. Some individuals, predominantly males, left the observation area cross-country, flying directly without obvious foraging behavior. In most of

Table 8. Numbers of bats and capture rates of four species of *Myotis* and six other species netted and trapped over streams (23 nights), summer 1976.

Species	Male adult	Male juv.	Female adult	Female juv.	Total	Bats caught per net per hour	Numerical rank
M. sodalis	22				22	.047	6
M. grisescens	87	36	47	28	201*	.429	2
M. lucifugus	10				10	.021	9
M. keenii	12	1	2	2	17	.036	7
Pipistrellus subflavus	35	11	25	4	77*	.164	3
Eptesicus fuscus	7	1	4	3	15	.032	8
Nycticeius humeralis		11	27	15	53	.113	4
Lasiurus borealis	105	48	45	67	267*	.571	1
Lasiurus cinereus	19	1	5	3	28	.060	5
Lasionycteris noctivagans	2				2	.004	10

* **Total includes unsexed bats.**

Table 9. Chemical light tracking, ground observations, 2 April-31 August 1976. The same individual may be observed performing more than one type of activity during one observation session (e.g. flying upstream plus foraging below 5 m plus drinking, so the percentages add up to over 100%).

Activity	*Myotis grisescens* (N=138) Total	Number of males	Number of females	Percent males	Percent females	Percent of total	*Myotis sodalis* (N=35; all males but 2) Percent	Number	*Myotis keenii* (N=11; all males but 1) Number	Percent
Cross country	43	15	21	40.5	22.8	31.2	42.9	15	11	100.0
Upstream	36	4	30	10.8	32.6	26.1	34.3	12	1	9.1
Downstream	76	19	54	51.4	58.7	55.1	28.6	10	2	18.2
Foraging over water	47	8	35	21.6	38.0	34.1	20.0	7	0	0.0
Foraging among trees	39	7	29	18.3	31.5	28.3	68.6	24	11	100.0
Foraging above 5 m	23	6	17	16.2	18.5	16.7	20.0	7	1	9.1
Foraging below 5 m	14	3	11	8.1	12.0	10.1	5.7	2	2	18.2
Milling around	32	5	23	13.5	25.0	23.2	5.7	2	0	0.0
Drinking	32	9	21	24.3	22.8	23.2	2.9	1	1	9.1

	Myotis grisescens	*Myotis sodalis*	*Myotis keenii*
Mean observation time, both sexes:	4.22 min.	4.30 min.	6.72 min.
Mean observation time, males:	2.97 min.	-	-
Mean observation time, females:	4.75 min.	-	-

the cases where compass direction was recorded, the bats' flight path would have taken them over water again in a few minutes. Bats flew downstream more often than upstream, suggesting that many preferred wider downstream portions of streams to the more narrow upstream portions. Netting over streams indicated that some M. grisescens use even the smallest of permanently-flowing streams, but larger numbers use the larger streams. Almost all mist-netting efforts turned up M. grisescens, which was second only to Lasiurus borealis (Table 8).

As compared to M. grisescens, a larger percentage of M. sodalis flew cross-country, and a larger percentage flew upstream toward narrower, more densely wooded areas. A very high percentage of the M. sodalis foraged among trees, rather than over water. Drinking and milling around (flight activity with no obvious direction or objective), both common behavior in M. grisescens were rarely observed in M. sodalis. The rarity of over-water flight was also evident in mist-net sampling, in which M. sodalis placed sixth among ten species captured (Table 8). Nevertheless, we knew that M. sodalis were present in larger numbers than suggested by mist-net sampling, because we caught as many as 200 males per night by erecting bat traps at selected caves, even in June and July.

Data for M. keenii suggest that these bats forage exclusively among trees, mostly in hillside and ridge forest, as opposed to riparian and flood plain forest. Some of the M. keenii observed foraged very low, over and among the tops of understory shrubs 1-3 m above the ground. Myotis keenii were observed for longer periods, on the average, than the other two species, primarily because the 11 individuals we watched began foraging shortly after release and doubled back frequently, flying away from the observers on a slow, irregular course. In contrast, many of the M. sodalis and M. grisescens flew directly away from the release point and disappeared within a minute.

In general, bats released during ground observation periods left the observation area within 10 min. or less. A single female M. grisescens tracked on 19 May was observed for 63 min. During this time she foraged continuously above the water along a 0.5 km section of river. Occasional forays were made into riverbank trees, but these were of brief duration. She foraged from just above the water to treetop level, but most commonly from 2-10 m above the water. At the end of the period she returned to the cave from which she had been released. Another female M. grisescens released on 18 May was observed foraging for 21 min., during which she flew at a height of less than 2 m over the water for much of the time.

A male M. sodalis, observed for 26 min. on 28 May, flew an elliptical pattern rarely exceeding 100 m in length at a given time (and frequently less than 50 m) that took him among trees within and along the edge of a small flood plain pasture. Mostly he maintained altitudes of 3-10 m. He abruptly ceased foraging and disappeared upstream in riparian forest. A second male *M. sodalis* foraged for 20 min. in dense forest along the ridge above his roosting cave on 19 June. On 28 May, two male *M. keenii* were observed for 14 and 15 min., respectively, foraging slowly among trees along the ridge.

Flight behavior data for *M. grisescens* and *M. sodalis*, based on helicopter observations, are summarized in Table 10.

That sightings of released bats ran as low as 30 percent, and no higher than 58 percent for *M. grisescens*, reflects the numerous events that could preclude sighting an individual bat: *i.e.* some lights fell off; some bats hung up below vegetation, or flew into a cave; others probably flew up small tributary streams or small valleys not flown over by the airborne observers; all these actions were observed from the ground. The lower sighting rate for *M. sodalis* probably reflects the normal foraging behavior we observed from the ground for that species, that is, flying slowly and erratically beneath the forest canopy.

The movement distances shown are maximums observed during the time periods shown. Bats may have moved farther up or downstream after observations were terminated. Flight speeds may be too high in some cases, as some bats were released before time 0000, which was helicopter take-off time. Also, some of the bats

Table 10. Observations from a helicopter of the flight of _M._ _grisescens_ and _M._ _sodalis_ marked by chemiluminescent liquid, 1976.

Date	Number of bats lighted	# Seen * w/o repeats	Percent	River@ distance		Time	Speed
3 June	45 _M._ _grisescens_	26	57.8	Upstream Downstream	14 km 11 km	50 min. 35 min.	17 km/hr. 19 km/hr.
1 July	**53 _M._ _grisescens_	16	30.2	Upstream Downstream	17 km 13 km	40 min. 20 min.	25 km/hr. 39 km/hr.
3 Aug.	42 _M._ _grisescens_	21	50.0	Upstream Downstream	7 km 10.5 km	15 min. 35 min.	29 km/hr. 18 km/hr.
30 Sept.	40 _M._ _sodalis_	7	17.5	Cross-country	2 km	-	-
Total	180	70	38.9				

* Number of bats seen on first pass up- and downstream in helicopter.

** Plus eight that returned to the cave and stayed there during the observation period.

@ Upstream = Maximum upstream movement observed.
Downstream = Maximum downstream movement observed.
Crosscountry = Maximum crosscountry distance observed.

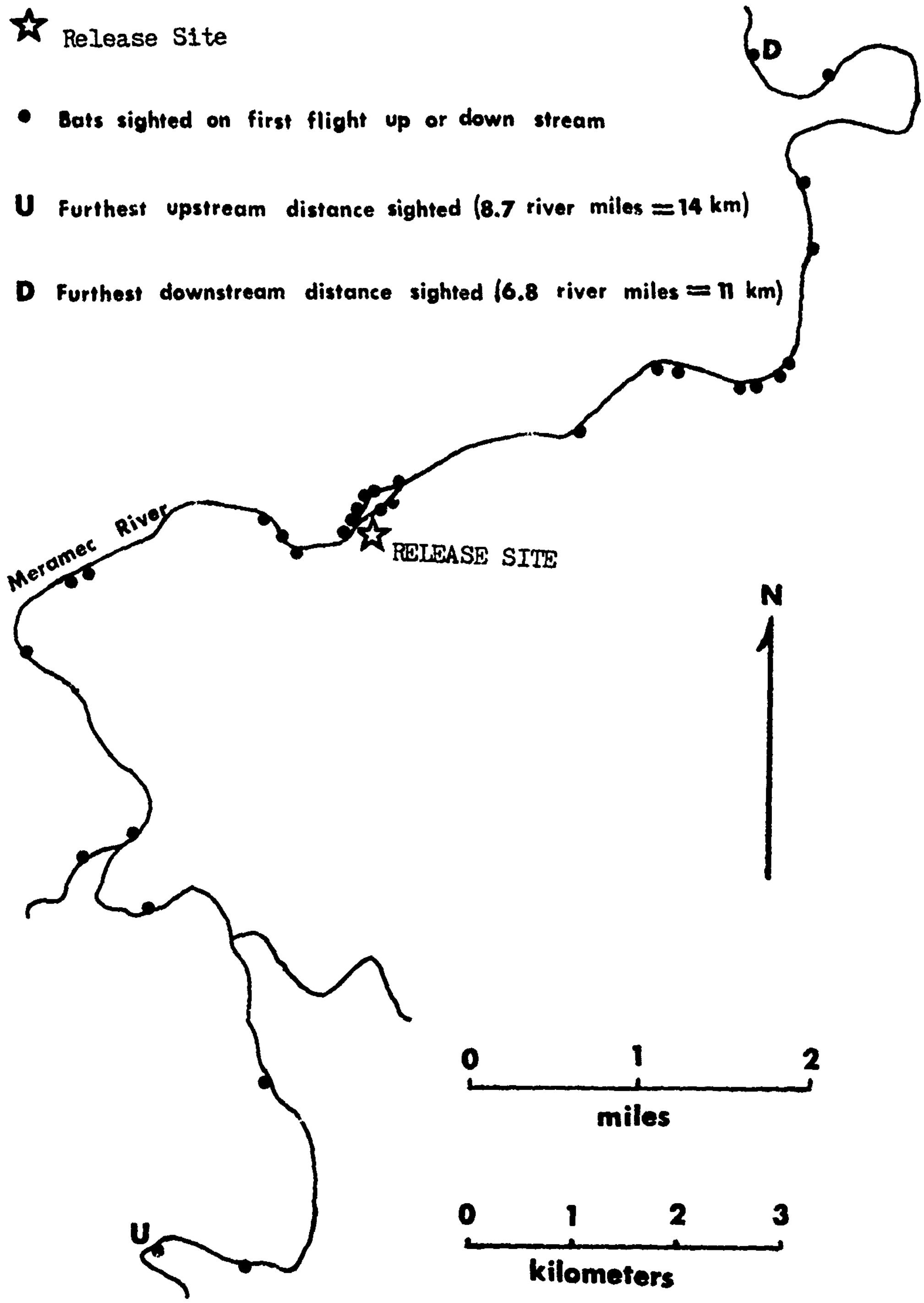


Fig. 4. Observed positions of M. grisescens, 3 June 1976.

may have reached maximum distance before the helicopter arrived over their position, so that some of the speeds may be too slow. Tuttle (1976b) calculated a mean flight speed of 20.3 km/hr. for migrating M. grisescens. In any case, it appears that M. grisescens often fly rapidly and directly to foraging sites. Forty percent of the bats were flying directly upstream or downstream, away from the cave. All M. grisescens observed foraging (56 percent) were over water, with brief forays into riparian vegetation. The bats tended to be concentrated (in twos and threes) adjacent to heavily wooded bluffs and hillsides. Few foraging M. grisescens were seen adjacent to pastures. Foraging areas seemed to be less than 1 km in length for individuals. When subsequent passes were made along the river in the helicopter, foraging bats, possibly the same individuals, were often observed in the same places as on the previous pass.

In Fig. 4, the places at which lighted M. grisescens were observed on 3 June are indicated by large dots. As can readily be observed, bats were spaced out along 25 km of river, but tended to be somewhat patchy in distribution.

On the night we released 34 dorsally lighted M. sodalis, 25 of the 34 bats were freed prior to take-off. We were unable to locate those bats. Of the nine subsequently released, 6 of 7 observed were first sighted and then followed from near the cave. All of these bats were foraging among trees in dense forest, mostly on hillsides and ridgetops. All were within 2 km of the release point during the observation period of one hour. Bats appeared to be foraging slowly within and among treetops but moved steadily ahead, rather than circling back. No bats were seen to fly over the nearby flood plain with its stream, pastures, and riparian vegetation. The bats observed disappeared from view at intervals, and after a few minutes, vanished completely. Thus it is not surprising that most of the bats released were never spotted from the helicopter.

In conclusion, it appears that the *M. grisescens* and *M. sodalis* in the Meramec Park Lake area partition their foraging habitat quite successfully. *M. grisescens* is restricted to streams and riparian forest. *M. sodalis* prefers flood plain, hillside, and ridge forests. Relatively small sample sizes for six other species that were lighted (plus twilight observations) suggest that *M. keenii* shares the *M. sodalis* habitat; *M. lucifugus* shares both habitats; *Lasiurus borealis* and *L. cinereus* feed high over forests and pastures; *Nycticeius humeralis* and *Pipistrellus subflavus* share the stream habitat with *M. grisescens*.

Observations made by Tuttle (1975) of *M. grisescens* generally concur with ours, even though his studies involved populations foraging over reservoirs rather than streams. On the other hand, Cope, *et al.* (1974), and Humphrey, *et al.* (1974), observing *M. sodalis* in Indiana, arrived at conclusions much different from ours. Their bats, mostly females and young, foraged over streams, in riparian habitat, and in forest edge on the flood plain. Our bats, mostly adult males, foraged in densely forested situations, most of them on hillsides and ridges. We suggest that riparian habitat may be optimum for M. sodalis, but that competitive exclusion of M. sodalis by M. grisescens in the Meramec area has forced M. sodalis to forage away from the streams. To avoid this problem, females may migrate northward, out of the range of M. grisescens, or in some other direction to areas where M. grisescens populations are minimal due to lack of suitable caves.

Tuttle (in litt.) observed that lactating females are likely to have smaller apparent foraging ranges than males because the females are unlikely to move from cave to cave. Although sample sizes in stream-netting (following paragraph) were not sufficiently large to demonstrate any such trends, data from maximum foraging movements shown in Table 8 suggest the reverse, because the M. grisescens with the greatest movements were lactating females (1 July). Bats on 3 June and 3 August were mostly males, with some juveniles on the later date.

Our observations on maximum foraging distance movements in M. grisescens are supported by recaptures of cave-banded bats in nets over streams (N= 27) and of stream-banded bats in caves (N= 17). In stream-netting, bats were captured a mean distance of 11.1 km (1.0-27.8 km) from the cave of banding. Stream-netted bats banded and later recaptured at caves were recaptured a mean distance of 12.5 km (2.5-35.4 km) from the site of banding. This data supports the hypothesis that M. *grisescens* have an extensive foraging range while occupying summer roosts. But at least some individuals choose the metabolically conservative strategy of foraging in the general vicinity of the one or several closely adjacent summer roost sites they use, as opposed to frequent longer-distance movements to other cave areas, perhaps along other Ozark rivers.

Phase II

Fall Population and Habitat Analysis

Although Phase II was intended to be limited to 1975, some additional supporting data were collected during the same period of 1976, and will be included here, when pertinent.

The movement of bats from maternity and summer roost areas to caves where prehibernation activities such as swarming (defined by Cope and Humphrey, 1977, as "a phenomenon in which large numbers of bats fly in and out of cave entrances from dusk to dawn, while relatively few roost in the caves during the day.") and copulation occur is certainly a critical phase of their life cycle. This period was defined by the Contract as 1 September through 30 November. However, because swarming activities take place throughout August, we are considering the initiation date for Phase

II to be 1 August. Swarming ends in early November, so no data are available for the remainder of that month.

There was but one way to determine beyond doubt that a cave was used by swarming bats - by placing a net or trap across the entrance. Mist nets were erected at three caves on separate nights; the trap was utilized on 34 nights at nine different caves during 1975, and on 21 nights at 10 different caves during 1976. Tables 11 and 12 show the comparable numbers of bats handled at caves during Phase II in 1975 and 1976, respectively. Most of these were trapped at the cave entrances. The relative proportions of the four species are remarkably constant for the two-year period.

Numbers of bats observed during Phase II (including some seen more than once) are recorded in Tables 13 and 14. Note that during 1976, few observations of hibernating bats were made, and a visit to a cave outside the project area (057) was included.

Swarming

Fig. 5, 6, 7, and 8 illustrate changes in swarming activity during the course of Phase II, with 1975 and 1976 data compared for each species. In this study the term "swarming" simply refers to the activity of bats flying in and out of cave entrances between 1 August and early November. No attempt is made to differentiate between the different purposes bats may have for

Table 11. Numbers of myotine bats handled during the period 1 August-30 November 1975.

Cave #	_M. sodalis_	_M. lucifugus_	_M. keenii_	_M. grisescens_	Totals
001	2	6	5		13
006	2	65	113		180
008	12	8	114	1	135
009	959	238	79	59	1335
017	586	195	59	27	867
021	784	82	3	407	1276
029	1720	99	178	115	2112
030	22	9		797	828
031	131	5			136
032	4	3		59	66
033	829	107		27	963
034				185	185
035				50	50
Totals	5051	817	551	1727	8146

Table 12. Numbers of myotine bats handled during the period 1 August-20 October 1976.

Cave #	*M. sodalis*	*M. lucifugus*	*M. keenii*	*M. grisescens*	Totals
006		30	134		164
008			2		2
009	566	200	174	12	952
017	163	109	43	6	321
021	630	37		197	864
022	41	84	45	9	179
029	1600	302	149	465	2516
030	16	8	8	564	596
031	8				8
033	1044	30	2	7	1083
034				33	33
035		3		70	73
036				107	107
039	5	5	17	112	139
044				37	37
057				4	4
Totals	4073	808	574	1623	7078

Table 13. Numbers of myotine bats observed during the period 1 August-30 November 1975.

Cave #	M. sodalis	M. lucifugus	M. keenii	M. grisescens	Totals
001		18			18
005		23			23
008		7	1		8
009	16477			560	17037
013	122	24			146
017	3832	6		600	4438
021	15370	93		778	16241
023				500	500
029	56884	1		2000	58885
030	25	1		7164	7190
031	8339	256			8595
032	5	18		203	226
034				550	550
035				500	500
036				7425	7425
037	14				14
038				6	6
Misc.	18	6	—	12	36
Totals	101086	453	1	20298	121838

Note: Some of these bats may have been observed more than once, as local movements between caves were fairly common. For the same reason, some bats may not have been observed at all. These effects tend to cancel each other out, giving a fairly reliable estimate.

Table 14. Numbers of myotine bats observed during the period 1 August - 20 October 1976.**

Cave #	*M. sodalis*	*M. lucifugus*	*M. keenii*	*M. grisescens*	Totals
021				40	40
023				375	375
029	26	4	2	1	33
030				7350	7350
031	1262				1262
035				75	75
036				9450	9450
044				122	122
045				2	2
057*	—	-	-	36450	36450
Totals	1288	4	2	53865	55159

* Outside project area

** See notes under Table 11.

Figure 5. Numbers of Myotis sodalis trapped at cave entrances, 1 August-7 November 1975 and 1 August-12 October 1976.

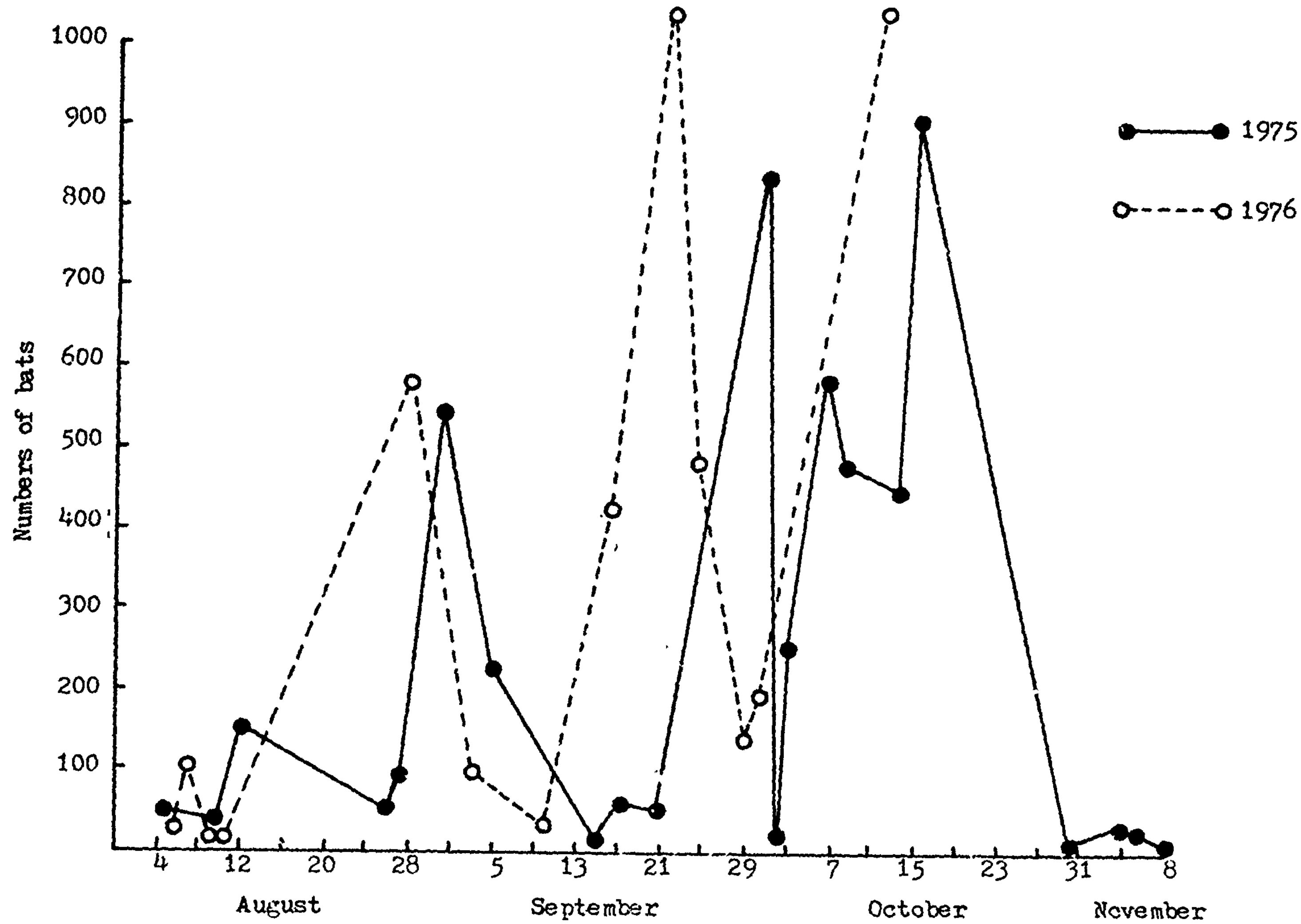


Figure 6. Numbers of Myotis lucifugus trapped at cave entrances, 1 August-7 November 1975 and 1 August-12 October 1976.

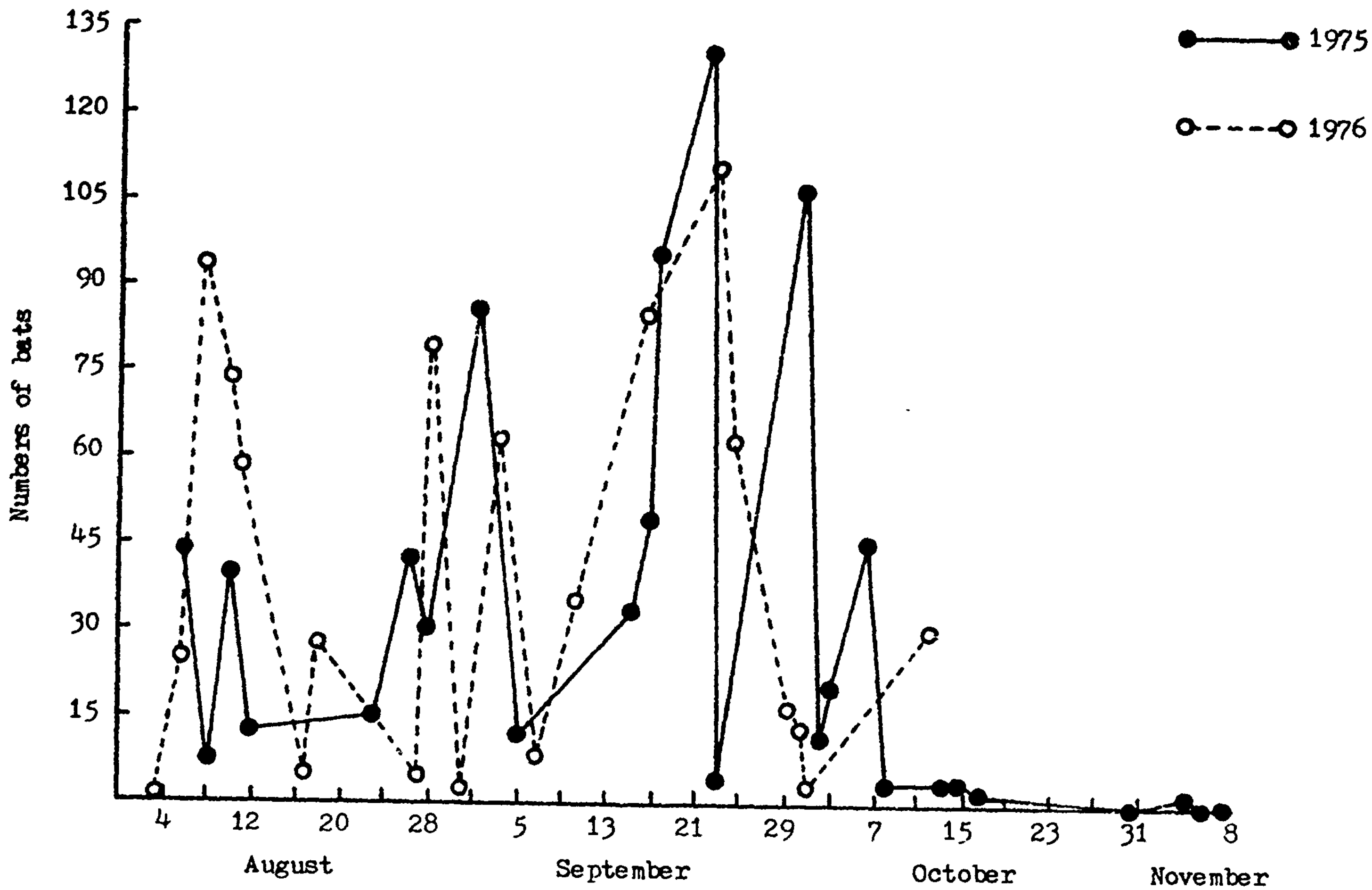


Figure 7. Numbers of *Myotis keenii* trapped at cave entrances, 1 August-7 November 1975 and 1 August-12 October 1976.

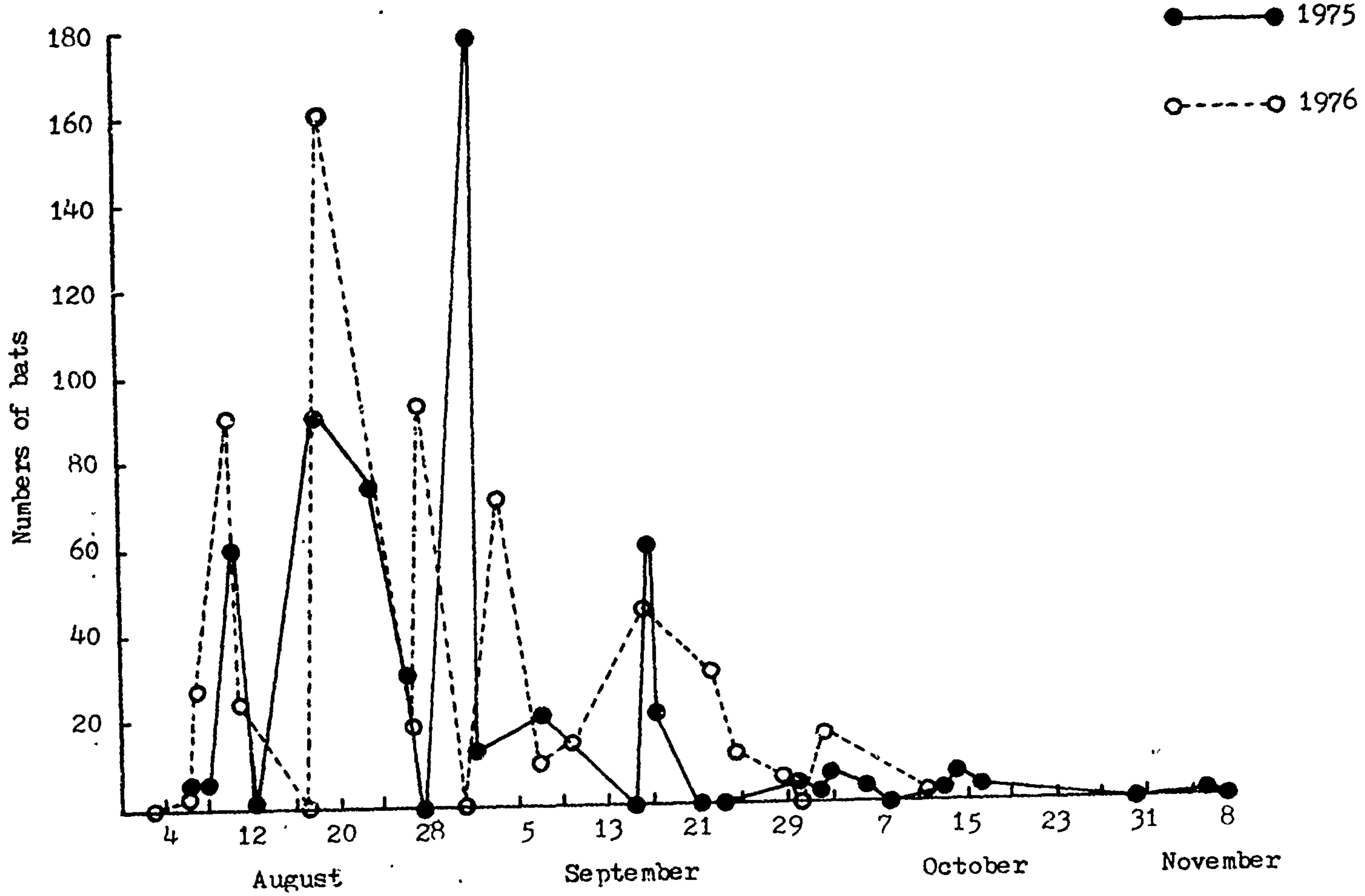
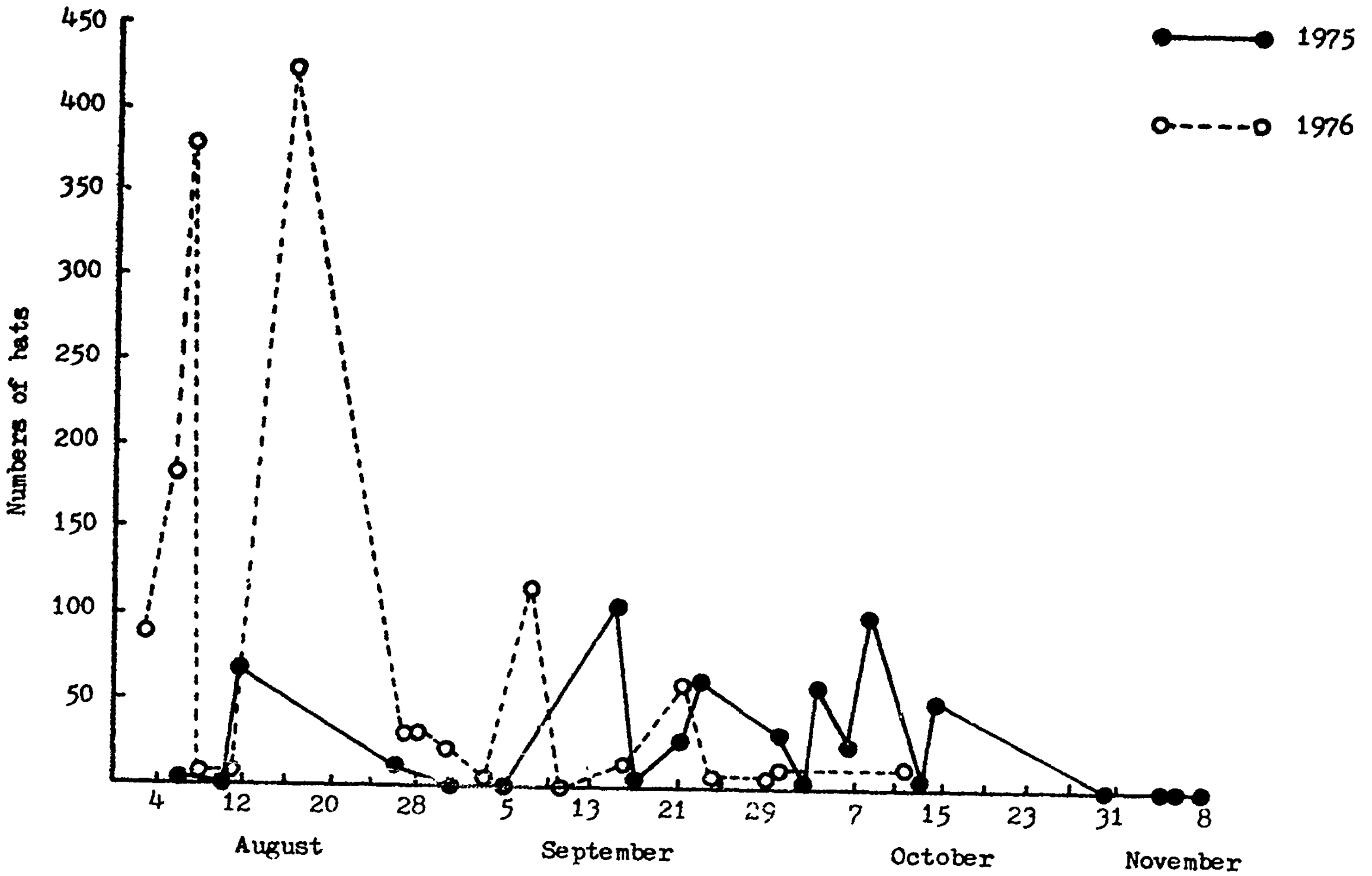


Figure 8. Numbers of Myotis grisescens trapped at cave entrances, 1 August-7 November 1975 and 1 August-12 October 1976.



using caves. M. Tuttle (in litt.) has pointed out that these purposes may include, but are not limited to, night roosting, traveling between two places within a home range, familiarization with seasonal range, migration rest stops, or copulating Most of these data were gathered at four M. sodalis hibernacula (009, 017, 021, and 029), except for M. grisescens data which are based on several transient roosts, especially 030 and 039. It appears that numbers of M. sodalis swarming reach three peaks, one at the August-September transition, one in mid- to late September, and a third in mid-October. Unseasonably cool weather during October and November 1976 (Fig. 9) would seem to be indicative of an early winter, seemingly predicted by the timing of M. sodalis activity peaks, earlier in 1976 than in 1975 (Fig. 5).

The swarming activity patterns of M. lucifugus are somewhat similar to those of M. sodalis, except that a relatively larger amount of M. lucifugus activity occurred during early August, and a relatively smaller amount during mid-October (Fig. 6).

In contrast, peaks of activity in M. keenii were confined to August and early September, with few individuals still being trapped after mid-September. Patterns exhibited in the two years were not consistent (Fig. 7).

The swarming patterns of M. grisescens are, as might be expected, quite different from the other species because the

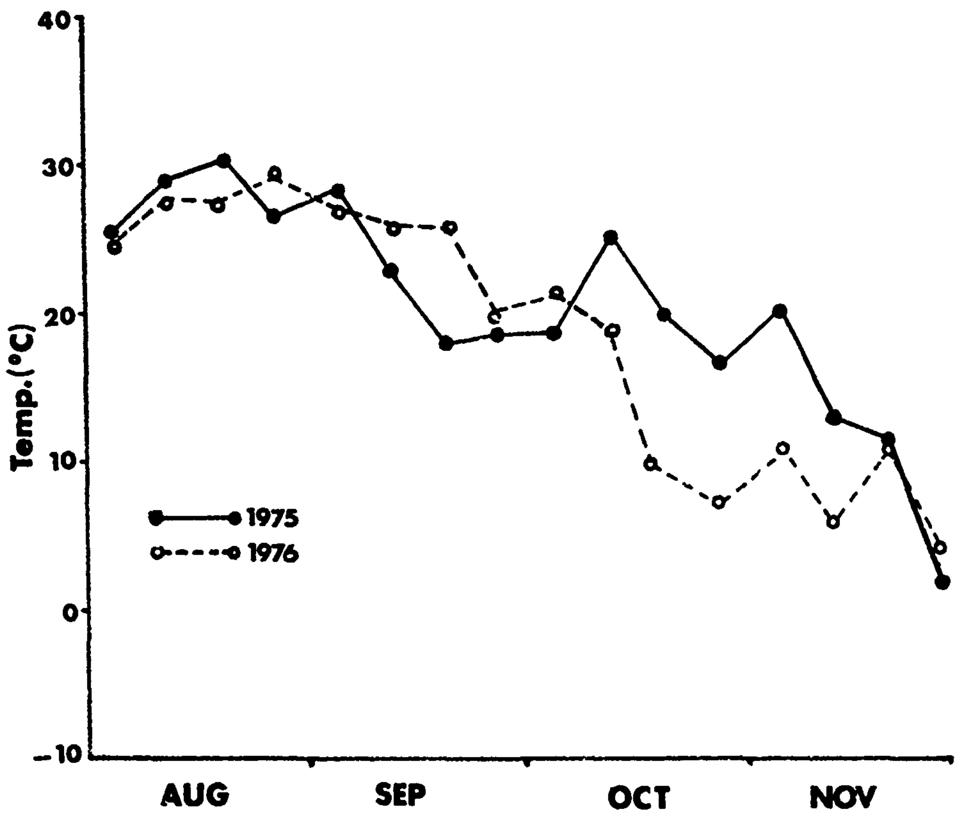


Fig. 9. Weekly mean midday temperatures, Missouri Department of Conservation, Sullivan, Missouri, 1 August through 30 November, 1975 and 1976.

M. grisescens have all left the project area by the end of the Phase II period. The discrepancy between the August data for 1975 and 1976 reflects our failure to trap two important M. grisescens caves in 1975. It appears that the M. grisescens left the area earlier in 1976 than in 1975 (Fig. 8), paralleling the behavior trends in M. sodalis that appear to relate to cold weather in 1976.

Patterns of swarming behavior of M. sodalis and M. lucifugus as documented by Cope and Hymphrey (1977), and Humphrey and Cope (1976) are similar to those observed by us, with a few deviations not discussed herein. Swarming behavior in the other two species is not well documented in the literature (see Barbour and Davis, 1969).

With the exception of M. grisescens, swarming bats were trapped only at caves later used as hibernacula. Banding data confirmed that bats tended to hibernate in the same cave in which they swarmed, although there were numerous intercave movements. To be precise, during 1975, 26 percent of the bats banded during swarming, and later recaptured, moved to another cave; the remaining 74 percent hibernated in the cave of banding.

Copulations in M. sodalis were observed as early as 16 September, and as late as 14 October, with numerous copulations seen during the interim. Myotis grisescens were observed copulating only twice, on 26 September and 4 October. Myotis lucifugus were observed copulating only once, on 16 September, and M. keenii were never observed copulating.

Shift from Maternity Sites to Hibernacula

The movements from maternity sites (called breeding areas in the Contract) to hibernacula were not documented in this study, because it was not initiated in time to band M. grisescens at maternity caves in 1975, and the other three species apparently raise few if any of their young in the study area. However, both juvenile and adult M. grisescens banded at transient caves in 1975 were later found at hibernacula 112 km south of the project area. Of 1438 M. grisescens banded during 1975, 374 were observed hibernating in caves south of the project area (046 and 047) on 17 and 18 March 1976. The total number observed on those days was 59000. We suspect that as many as half the bats had already left the hibernacula, because Myers (in litt.) reported a mean total of 117000 M. grisescens in cave 046, based on observations made during January of 1966, 1968, 1971, and 1972. In any case, our count is probably low; we believe at least half of the bats from the project area hibernate in those two caves. Of 28 M. grisescens in the hibernacula whose band numbers were recorded, six were later recaptured at caves back in the project area.

Equally enlightening is the dispersal pattern of juveniles and adult females banded at maternity caves during June and July

1976 (Table 15; Fig. 10). Only at maternity cave 054 were significant numbers of bats banded (N=644), although a few (N=71) were also banded at maternity cave 048, near the proposed Union Lake. The table shows that juvenile male bats from cave 054 dispersed uniformly among the caves sampled, in that percentages of these banded bats caught at each cave were similar to percentages of unbanded juvenile males captured at each cave. On the other hand, a notably higher percentage of juvenile females went to caves 030, 034, and 048, with a lower percentage going to 039 (a male roost) or returning to 054. Among adult females, a very strong preference for cave 030 was noted. During late summer, this cave is populated primarily by females. In summary, it appears that young males dispersed themselves randomly among _M. grisescens_ roost caves after leaving the maternity colony. Females of all ages, however, tend to congregate at cave 030, even though a few individuals were found at all the _M. grisescens_ roost caves.

During this study, relatively few bats banded in the project area were recaptured outside the area, with the exception of _M. grisescens_ at the two hibernacula. Furthermore, as previously noted, three of the species of myotine bats raised few or no young in the area, so females and young were not banded during the maternity period. Males, however, were present and were banded. Thus, although we cannot document shifts of juvenile and female _M. sodalis_, _M. keenii_, or _M. lucifugus_

Table 15. Movements of <u>Myotis grisescens</u> from the maternity sites, 1976. Bats "caught" is the number of unbanded bats captured, while "recap'd" bats have been previously caught and banded.

Caves		Juveniles							
		Males				Females			
From	To	# recap'd	%	# caught	%	# recap'd	%	# caught	%
048	030					2	40.0	156	50.5
"	039					1	20.0	124	40.1
"	048					2	40.0	29	9.4
						5		309	
054	009					1	3.0	14	2.5
"	021	4	8.3	55	8.3	2	6.1	53	9.6
"	029	8	16.7	123	18.6	2	6.1	52	9.4
"	030	14	29.2	169	25.6	14	42.4	156	28.2
"	034	3	6.3	12	1.8	4	12.1	15	2.7
"	039	11	22.9	172	26.0	5	15.2	124	22.4
"	048	2	4.2	30	4.5	3	9.1	29	5.2
"	054	5	10.4	93	14.1	1	3.0	109	19.7
"	Brazil Creek	1	2.1	7	1.1				
"	Kratz Spring					1	3.0	2	0.4
		48		661		33		554	

Table 15. (Continued)

Caves		Adult Females			
From	To	# recap'd	%	# caught	%
054	021	1	4.8	82	13.5
"	030	11	52.4	169	27.8
"	034	2	9.5	38	6.3
"	039	4	19.0	169	27.8
"	048	1	4.8	44	7.2
"	054	1	4.8	100	16.5
"	Prazil Creek	1	4.8	5	0.8
		21		607	

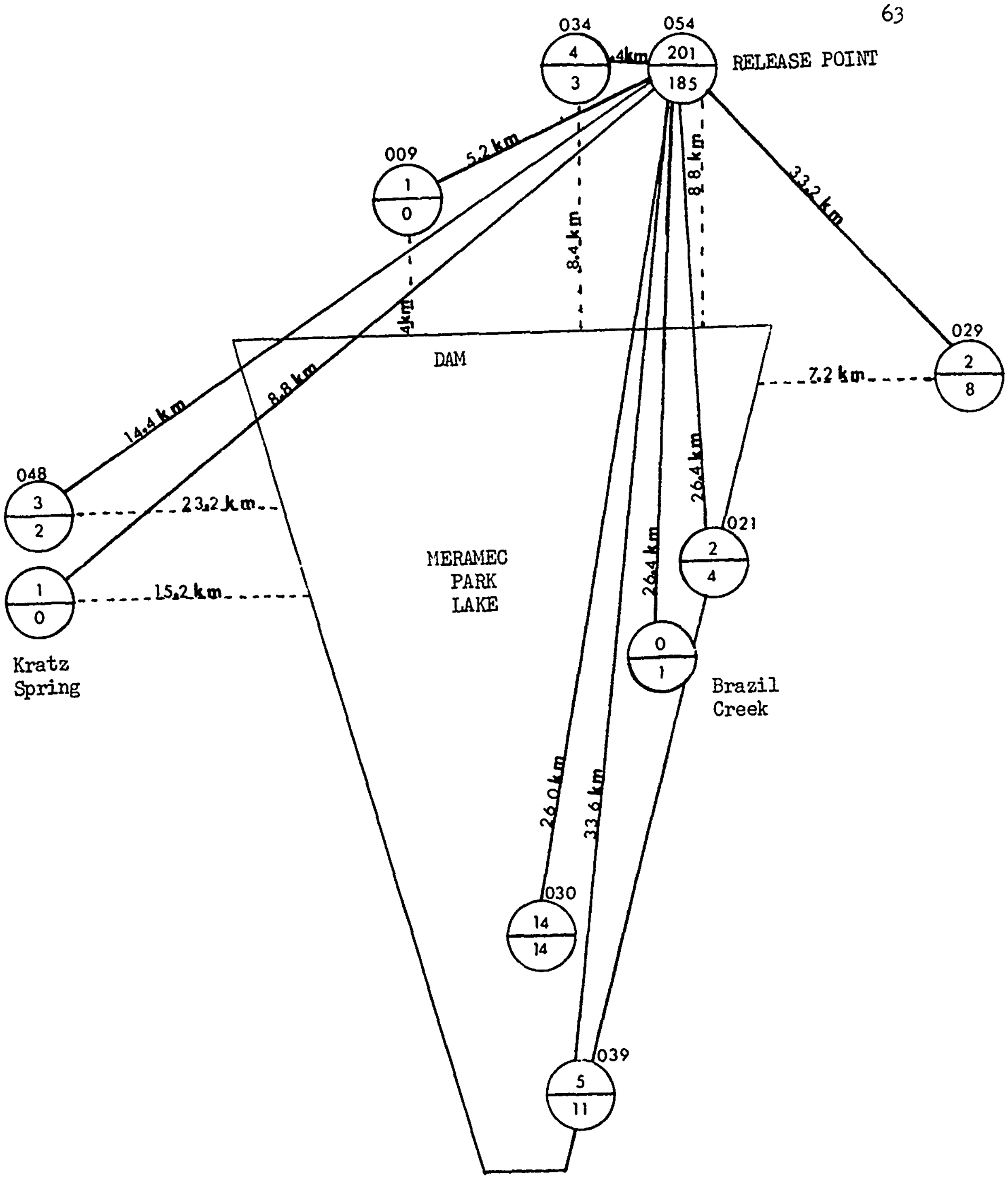


Fig. 10. Relative positions of caves and streams at which juvenile M. grisescens banded in cave 054 during June and early July 1976 were recaptured. Cave numbers are outside the circles representing the caves, and numbers of juveniles recaptured are inside the circles (females above, males below). In the case of cave 054, the numbers within the circle represent total numbers of juveniles banded of each sex. Figures given along dotted lines represent distances between caves and the edge of the lake; those along solid lines represent distances between release point and recapture site.

from maternity sites to hibernacula, we can examine recaptures of males banded during the maternity season (defined here as extending from the last week of May through the second week of July). Of twelve male *M. sodalis* banded during the maternity season (of 1976) and later recaptured, ten were caught later in the summer or fall at the cave of banding. One was found dead at a cave 31 km northeast of the banding site. Another, banded over a creek, flew to a nearby hibernaculum. Among six male *M. keenii* and five male *M. lucifugus* banded during the maternity season and later recaptured, all were taken at the cave of banding during summer or fall. Thus it appears that some males of these three species spend much (if not all) of the year within the project area. In the case of *M. sodalis*, however, most of the males, as well as all of the females, apparently leave the project area during the spring and do not return until the fall swarming period.

Myers (1964) documented migratory movements of myotine bats in Missouri. Among bats banded in the Ozarks, he recaptured several *M. sodalis* north of the Missouri River and one in Iowa. Pregnant female *M. sodalis* have also been found in northwestern Missouri (Easterla and Watkins, 1969). Myers (1964) recaptured a number of *M. lucifugus* banded in eastern Missouri and Illinois, north and northeast of the hibernacula where banded. In the present study two *M. lucifugus* were recaptured 40 km west and 48 km northeast, respectively, of the caves of banding. Two *M. lucifugus* banded in the summer in Illinois were recaptured by us in hibernacula, 240 km south of the banding site. Two *M. sodalis* flew 112 km south to cave

047. A single M. keenii flew 56 km northeast from the project area. These movements and recaptures demonstrate that the myotine bats resident in the project area are capable of flights of up to several hundred miles, and that many bats may make such flights. The M. sodalis in northwestern Missouri, for example, are 140 miles from any known hibernaculum.

Bats of the three species that hibernate in the project area leave during the spring (probably northward) and return in the fall; while M. grisescens move into the area in the spring and depart in the fall. Thus, the Meramec Park Lake area is of critical importance to populations of bats that occupy a range encompassing at least three states: Missouri, Illinois, and Iowa.

Phase III

Hibernating Populations and Habitat Analysis

Hibernation is an especially critical phase in the life cycle of those bats that hibernate, because, being torpid, they are easily susceptible to disturbance and vandalism. As they must survive through the winter on fat deposited in the fall, repeated arousals resulting from disturbance lead to significant weight loss in M. lucifugus (Fenton, 1970) and may lead to unsustainable levels of mortality in M. sodalis (see Humphrey, 1977). In the Meramec Lake area, M. lucifugus, and, to a greater degree, M. sodalis, are concentrated in highly vulnerable clusters in relatively few caves. In the case of the endangered M. sodalis, Humphrey (1977) estimated that 79 percent (280500) of the 354393 M. sodalis existing in 1975 hibernated in Missouri. Thirty-three and one half percent (118750) of the known U. S. population of *M. sodalis* hibernated in four Meramec Lake area caves.

In order to learn as much as possible about winter habitat requirements of hibernating myotine bats, a total of 77 caves was visited during Phase III, to bring to 122 the number investigated to that point. Information was gathered on an additional 99 caves from the files of the Missouri Speleological Survey, from interviews with spelunkers, and from miscellaneous sources. These 99 caves were judged to be unsuitable for myotine bats and were not subjected to further investigation. Suitability was based on criteria such as cave length, ceiling height, etc. In general, only caves that were reported to be short with low ceilings were rejected without being scrutinized by us.

One hundred forty one visits were made to 77 caves for the purpose of counting hibernating bats and recording environmental data. The five major *M. sodalis* hibernacula were each visited five times. The total of maximum monthly counts of myotine bats observed in caves within the project area during the period October-April was 86936 (74621 *M. sodalis*; 11363 *M. grisescens*; 913 *M. lucifugus*; 39 *M. keenii*; see Tables 16-19). Note the contrast in numbers of *M. sodalis* in this study as opposed to

Table 16. Numbers of Myotis sodalis observed at caves in the Meramec Park Lake area, October 1975-April 1976.

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
001	-	0	-	0	-	0	-
002	-	0	-	-	-	-	-
003	-	1	-	-	-	-	-
005	0	0	-	0	-	0	-
006	-	-	0	-	-	1	-
008	-	0	-	-	-	-	-
009	6744	9733	15528	12618	-	10679	1074
013(N)	-	122	-	119	-	121	-
015(N)	0	-	-	0	-	-	-
017	1238	2143	2974	1867	-	2076	54
020(F)	-	-	0	-	-	-	-
021	8212	8333	10787	10130	-	10786	223
022(F)	-	-	-	1	-	1	-
023(N)	0	0	-	3	-	0	0
024(N)	-	-	-	0	-	-	-
026	-	-	0	-	-	-	-
027(F)	-	-	0	-	-	-	-
029	21824	36605	38859	46606	-	37896	1435
030(N)	?	47	38	-	-	2	0
031	2930	5483	2466	3266	-	3434	72
032	11	5	-	7	-	3	0
034	0	0	-	0	-	0	0
035	0	0	-	1	-	0	0
036	0	0	0	-	-	1	0
037(F)	-	14	-	-	0	0	-
038	-	0	-	-	-	-	-
039(F)	0	0	-	-	0	-	-
040	-	-	6	-	-	0	-
041(F)	-	-	13	-	0	1	-
042	-	-	-	3	-	0	-
043(+)	-	-	-	-	458	-	-
044(F)	-	-	-	-	-	15	0
045	-	-	-	-	-	33	-
046(+)	-	-	-	-	-	15	-

N Within normal pool
F Within flood pool
- No visit that month
? No estimate made
+ Outside project area

Table 16. (Cont'd)

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr.
047(+)	-	-	-	-	-	46002	-
048	-	0	-	-	-	0	0
049	-	0	-	-	-	0	0
050	-	-	-	-	-	18	-
051	-	-	-	-	-	18	-
052	-	-	-	-	-	4	-
053(+)	-	-	-	-	-	50	-
C001(N)	-	-	-	-	-	0	-
C011(N)	-	-	-	-	0	-	-
C016(N)	-	-	0	-	-	-	-
C017(N)	-	-	0	-	-	-	-
C018	-	-	0	-	-	-	-
C021	-	-	-	-	-	-	0
C024	-	-	-	0	-	-	-
C028(F)	1	-	-	0	-	-	-
C047	-	-	0	-	-	-	-
C059	-	-	-	0	-	-	-
C066	-	-	-	-	0	-	-
C076	0	-	-	0	-	-	-
C102(N)	-	-	-	0	-	-	-
C104(N)	-	-	0	-	-	-	-
C111	0	-	-	0	-	-	-
C116	-	-	-	0	-	-	-
C123(F)	-	-	-	0	-	-	-
C130(N)	-	-	0	-	-	-	-
C136	-	-	-	-	0	-	-
F006	-	0	-	0	-	-	-
F015	-	-	0	-	-	-	-
F035	-	-	-	0	-	-	-
W005	-	1	-	-	-	-	-
W042	-	-	-	0	-	-	-
Totals	40960	62487	70665	74621	458	111156	2858

Table 17. Numbers of Myotis grisescens observed at caves in the Meramec Park Lake area, October 1975-April 1976.

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
001	-	0	-	0	-	0	-
002	-	0	-	-	-	-	-
003	-	0	-	-	-	-	-
005	1	0	-	0	-	0	-
006	-	-	0	-	-	1	-
008	-	0	-	-	-	-	-
009	550	60	12	0	-	0	15
013(N)	-	0	-	0	-	0	-
015(N)	8	-	-	0	-	-	-
017	0	0	3	0	-	0	0
020(F)	-	-	0	-	-	-	-
021	768	10	1	1	-	?	1765
022(F)	-	-	-	0	-	0	-
023(N)	500	0	-	0	-	0	2
024(N)	-	-	-	0	-	-	-
026	-	-	0	-	-	-	-
027(F)	-	-	0	-	-	-	-
029	1000	1000	500	150	-	400	215
030(N)	468	7	0	-	-	6	187
031	0	0	0	0	-	0	0
032	200	3	-	0	-	8	305
034	300	0	-	0	-	107	1350
035	500	0	-	0	-	5	700
036	675	0	0	-	-	219	4855
037(F)	-	0	-	-	0	0	-
038	-	0	-	-	-	-	-
039(F)	0	0	-	-	0	-	-
040	-	-	0	-	-	0	-
041(F)	-	-	0	-	0	0	-
042	-	-	-	0	-	0	-
043(+)	-	-	-	-	34	-	-
044(F)	-	-	-	-	-	0	1368
045	-	-	-	-	-	0	-
046(+)	-	-	-	-	-	53905	-

N Within normal pool
F Within flood pool
- No visit that month
? No estimate made
+ Outside project area

Table 17. (Cont'd)

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
047( )	-	-	-	-	-	9096	-
048	-	0	-	-	-	0	600
049	-	0	-	-	-	0	1
050	-	-	-	-	-	0	-
051	-	-	-	-	-	0	-
052	-	-	-	-	-	0	-
053( )	-	-	-	-	-	0	-
054	0	-	-	-	-	-	0
C001(N)	-	-	-	-	-	0	-
C011(N)	-	-	-	-	0	-	-
C016(N)	-	-	0	-	-	-	-
C017(N)	-	-	0	-	-	-	-
C018	-	-	0	-	-	-	-
C021	-	-	-	-	-	-	0
C024	-	-	-	0	-	-	-
C028(F)	0	-	-	0	-	-	-
C047	-	-	0	-	-	-	-
C059	-	-	-	0	-	-	-
C066	-	-	-	-	0	-	-
C076	3	-	-	0	-	-	-
C102(N)	-	-	-	0	-	-	-
C104(N)	-	-	0	-	-	-	-
C111	0	-	-	0	-	-	-
C116	-	-	-	0	-	-	-
C123(F)	-	-	-	0	-	-	-
C130(N)	-	-	0	-	-	-	-
C136	-	-	-	-	0	-	-
F006	-	0	-	0	-	-	-
F015	-	-	0	-	-	-	-
F035	-	-	-	0	-	-	-
W005	-	0	-	-	-	-	-
W042	-	-	-	0	-	-	-
Totals	4973	1080	516	151	34	63747	11363

Table 18. Numbers of Myotis lucifugus observed at caves in the Meramec Park Lake area, October 1975-April 1976.

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
001	-	18	-	6	-	4	-
002	-	0	-	-	-	-	-
003	-	0	-	-	-	-	-
005	0	23	-	8	-	10	-
006	-	-	23	-	-	12	-
008	-	7	-	-	-	-	-
009	4	0	6	55	-	72	19
013(N)	-	24	-	7	-	2	-
015(N)	1	-	-	0	-	-	-
017	3	2	211	312	-	286	26
020(F)	-	-	0	-	-	-	-
021	0	9	102	62	-	89	13
022(F)	-	-	-	198	-	178	-
023(N)	0	0	-	6	-	0	0
024(N)	-	-	-	0	-	-	-
026	-	-	0	-	-	-	-
027(F)	-	-	0	-	-		-
029	0	1	27	16	-	42	5
030(N)	0	0	5	-	-	0	1
031	4	3	172	214	-	137	27
032	3	15	-	0	-	0	0
034	0	0	-	0	-	0	0
035	0	0	-	0	-	1	0
036	0	0	0	-	-	0	0
037(F)	-	0	-	-	2	1	-
038	-	0	-	-	-	-	-
039(F)	0	0	-	-	1	-	-
040	-	-	0	-	-	0	-
041(F)	-	-	0	-	0	0	-
042	-	-	-	6	-	1	-
043(+)	-	-	-	-	0	-	-
044(F)	-	-	-	-	-	14	0
045	-	-	-	-	-	20	-
046(+)	-	-	-	-	-	0	-

N Within normal pool
F Within flood pool
- No visit that month
? No estimate made
+ Outside project area

Table 18. (Cont'd)

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
047(+)	-	-	-	-	-	0	-
048	-	0	-	-	-	0	0
049	-	0	-	-	-	0	0
050	-	-	-	-	-	0	-
051	-	-	-	-	-	1	-
052	-	-	-	-	-	0	-
053(+)	-	-	-	-	-	2	-
C001(N)	-	-	-	-	-	0	-
C011(N)	-	-	-	-	0	-	-
C016(N)	-	-	0	-	-	-	-
C017(N)	-	-	0	-	-	-	-
C018	-	-	0	-	-	-	-
C021	-	-	-	-	-	-	0
C024	-	-	-	0	-	-	-
C028(F)	0	-	-	0	-	-	-
C047	-	-	0	-	-	-	-
C059	-	-	-	0	-	-	-
C066	-	-	-	-	0	-	-
C076	0	-	-	1	-	-	-
C102(N)	-	-	-	0	-	-	-
C104(N)	-	-	0	-	-	-	-
C1'1	0	-	-	0	-	-	-
C116	-	-	-	1	-	-	-
C123(F)	-	-	-	0	-	-	-
C130(N)	-	-	0	-	-	-	-
C136	-	-	-	-	2	-	-
F006	-	0	-	17	-	-	-
F015	-	-	0	-	-	-	-
F035	-	-	-	2	-	-	-
W005	-	0	-	-	-	-	-
W042	-	-	-	2	-	-	-
Totals	15	102	546	913	5	872	91

Table 19. Numbers of <u>Myotis keenii</u> observed at caves in the Meramec Park Lake area, October 1975-April 1976.

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
001	-	0	-	0	-	2	-
002	-	0	-	-	-	-	-
003	-	0	-	-	-	-	-
005	0	1	-	0	-	3	-
006	-	-	0	-	-	4	-
008	-	0	-	-	-	-	-
009	0	0	0	0	-	0	0
013(N)	-	0	-	0	-	1	-
015(N)	0	-	-	0	-	-	-
017	0	0	0	0	-	0	0
020(F)	-	-	1	-	-	-	-
021	0	0	0	0	-	0	0
022(F)	-	-	-	0	-	0	-
023(N)	0	0	-	0	-	0	0
024(N)	-	-	-	0	-	-	-
026	-	-	0	-	-	-	-
027(F)	-	-	0	-	-	-	-
029	0	0	0	0	-	0	0
030(N)	0	0	0	-	-	0	0
031	0	0	0	0	-	0	0
032	0	0	-	0	-	0	0
034	0	0	-	0	-	0	0
035	0	0	-	0	-	0	0
036	0	0	0	-	-	0	0
037(F)	-	0	-	-	0	0	-
038	-	0	-	-	-	-	-
039(F)	0	0	-	-	0	-	-
040	-	-	0	-	-	0	-
041(F)	-	-	0	-	0	0	-
042	-	-	-	0	-	21	-
043(+)	-	-	-	-	0	-	-
044(F)	-	-	-	-	-	1	0
045	-	-	-	-	-	6	-
046(+)	-	-	-	-	-	6	-

N Within normal pool
F Within flood pool
- No visit that month
? No estimate made
+ Outside project area

Table 19. (Cont'd)

Cave #	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
047(+)	-	-	-	-	-	0	-
048	-	0	-	-	-	0	0
049	-	0	-	-	-	0	0
050	-	-	-	-	-	0	-
051	-	-	-	-	-	0	-
052	-	-	-	-	-	0	-
053(+)	-	-	-	-	-	1	-
C001(N)	-	-	-	-	-	0	-
C011(N)	-	-	-	-	0	-	-
C016(N)	-	-	0	-	-	-	-
C017(N)	-	-	0	-	-	-	-
C018	-	-	0	-	-	-	-
C021	-	-	-	-	-	-	1
C024	-	-	-	0	-	-	-
C028(F)	0	-	-	0	-	-	-
C047	-	-	0	-	-	-	-
C059	-	-	-	0	-	-	-
C066	-	-	-	-	0	-	0
C076	0	-	-	0	-	-	-
C102(N)	-	-	-	0	-	-	-
C104(N)	-	-	-	0	-	-	-
C104(N)	-	-	0	-	-	-	-
C111	0	-	-	0	-	-	-
C116	-	-	-	0	-	-	-
C123(F)	-	-	-	0	-	-	-
C130(N)	-	-	0	-	-	-	-
C136	-	-	-	-	0	-	-
F006	0	-	-	0	-	-	-
F015	-	-	0	-	-	-	-
F035	-	-	-	C	-	-	-
W005	-	0	-	-	-	-	-
W042	-	-	-	0	-	-	-
Totals	0	1	2	0	0	39	1

the count of 118750 made by S. R. Humphrey and T. L. Vogel in March 1975 (Humphrey, 1976; 1977). Because hibernating bats were normally not handled, relatively little information was obtained on sex ratios. However, during the week of 8-12 March, 746 *M. sodalis* were examined in the hibernacula. Of these, 431 were females and 315 males, a ratio of about 4:3.

Myotis sodalis

Relative humidities ranged from 57 to 97 percent, with readings in excess of 74 percent at all major *M. sodalis* hibernacula. Within the range of 74 to 97 percent there seemed to be no correlation between locations of hibernating bats and humidity. Humphrey (1977) reported humidities in excess of 75 percent in the hibernacula he investigated. Standing or flowing water was found under or adjacent to fewer than one half of all hibernating bats observed in this study, and one major *M. sodalis* hibernaculum (cave 009) contained no surface water.

Cluster temperatures and rock temperatures (of cave ceiling adjacent to bat clusters) measured with an infrared thermometer, and air temperatures (below bat clusters) measured with a mercury thermometer for the five major *M. sodalis* hibernacula are recorded in Table 20. As can easily be seen from the table, *M. sodalis* prefer caves in which environmental temperatures are relatively low during the December-March period, but in which

Table 20. Temperatures recorded adjacent to hibernating *Myotis sodalis* at sites at which the majority of the bats were congregated, based on one visit per month, October 1975 - April 1976.

Cave #		Oct.	Nov.	Dec.	Jan.	Mar.	Apr.
009	T_{air}	12.0	12.0	10.5	9.6	11.2	12.4
	T_{rock}	-	9	9	8	10	-
	T_{bats}	-	10	-	8	10	-
017	T_{air}	13.0	12.4	8.2	8.0	9.8	11.6
	T_{rock}	12	10	8	7	8	-
	T_{bats}	-	10	8	7	8	-
021	T_{air}	12.2	12.5	10.2	6.8	9.2	9.6
	T_{rock}	-	8	8	7	8	10
	T_{bats}	-	8	-	-	8	10
029	T_{air}	12.8	12.8	9.4	2.8	11.2	11.2
	T_{rock}	12	12	10	6	11	-
	T_{bats}	12	-	-	5.5	-	-
031	T_{air}	13.8	13.8	10.2	6.2	9.0	10.6
	T_{rock}	-	12	10	6	8	-
	T_{bats}	-	-	10	6	8	-

the bats do not encounter sub-freezing temperatures. Several caves, most notably 006, 013, and W5, appear to offer optimal environmental conditions for hibernating M. sodalis. However, all three of these caves have been subjected to frequent and serious disturbance, with the result that few M. sodalis were present. Temperatures were recorded at virtually all other caves investigated during Phase III. Most of these were too warm, although in a few it appeared that subfreezing temperatures had occurred. Optimal mid-winter temperatures at clustering sites are 4-8°C (Humphrey, 1977). Any M. sodalis attempting to hibernate in these sub-optimal caves would almost certainly have a reduced chance of surviving the period of hibernation.

Temperatures of M. sodalis clusters approximated the rock temperatures (plus or minus 1°C) of the substrate to which the bats clung, as measured by the infrared thermometer. Bat body temperature is determined by temperature of the rock on which the bats are roosting, according to McNab (1974). It was not possible to measure temperatures of other hibernating myotine bats, as they were roosting only as individuals or in very small clusters, and we preferred not to remove them from roost sites for purposes of body temperature measurement.

In Fig. 11-15, which are based on MSS survey maps and personal knowledge, midwinter roosting sites of hibernating M. sodalis in the five caves are shown. Most of these sites

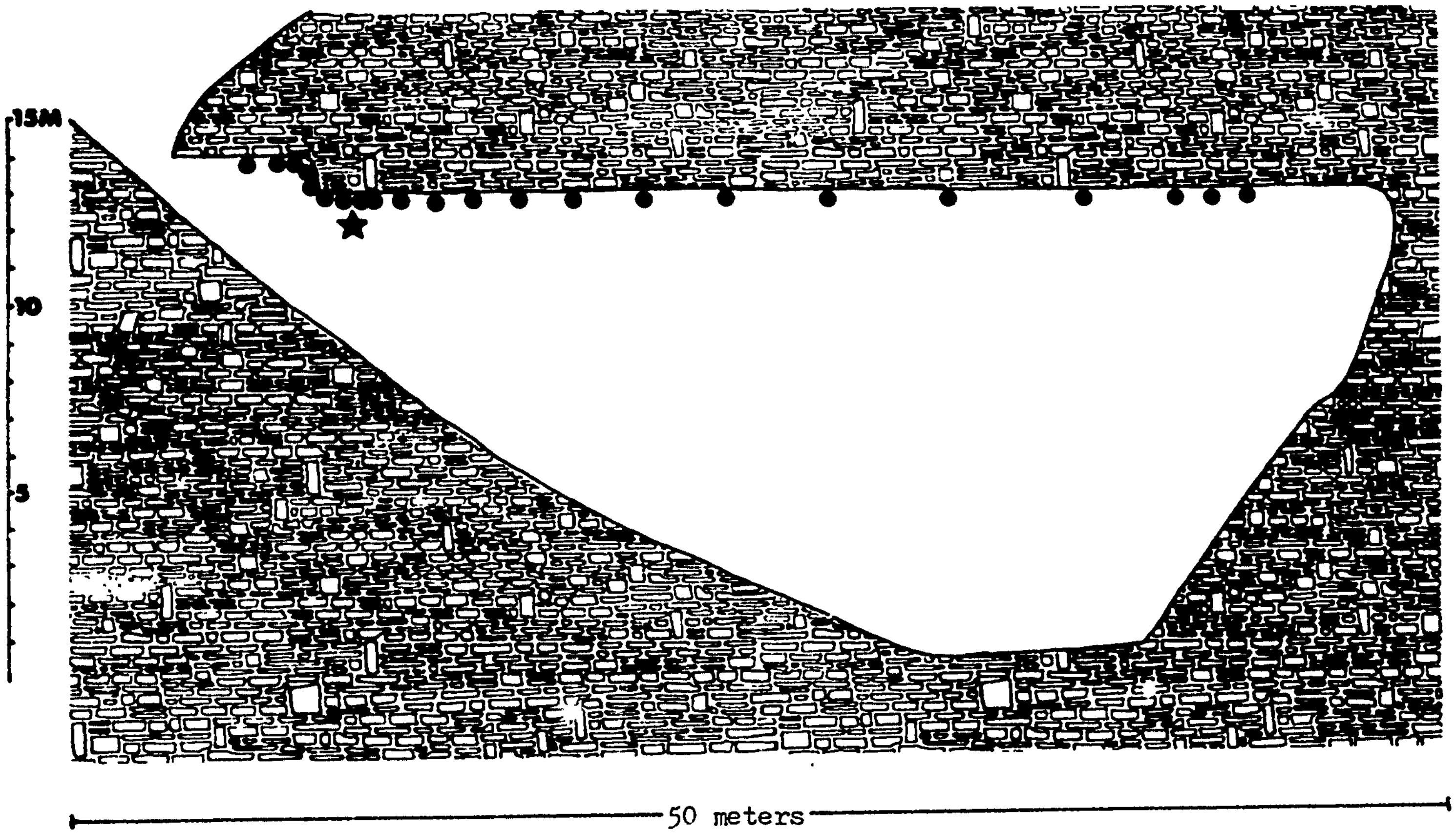


Fig. 11. Longitudinal section of cave 009. This and following cave sections are based on cave survey maps residing in the files of the Missouri Geological Survey. Dots (●) represent clusters of torpid _Myotis sodalis_ as of January 1976. Stars represent sites at which active _M. sodalis_ congregate when disturbed.

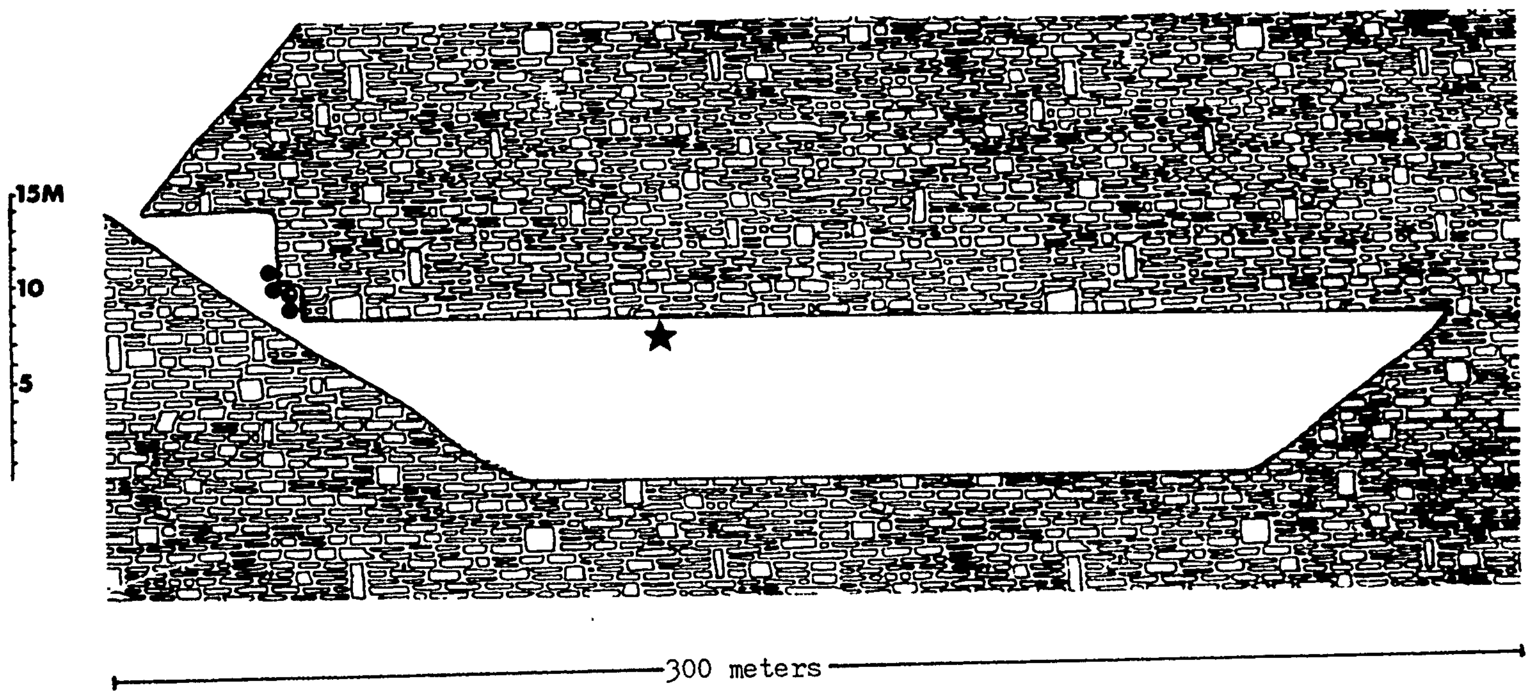


Fig. 12. Longitudinal section of cave 017. For interpretation of symbols see Fig. 11.

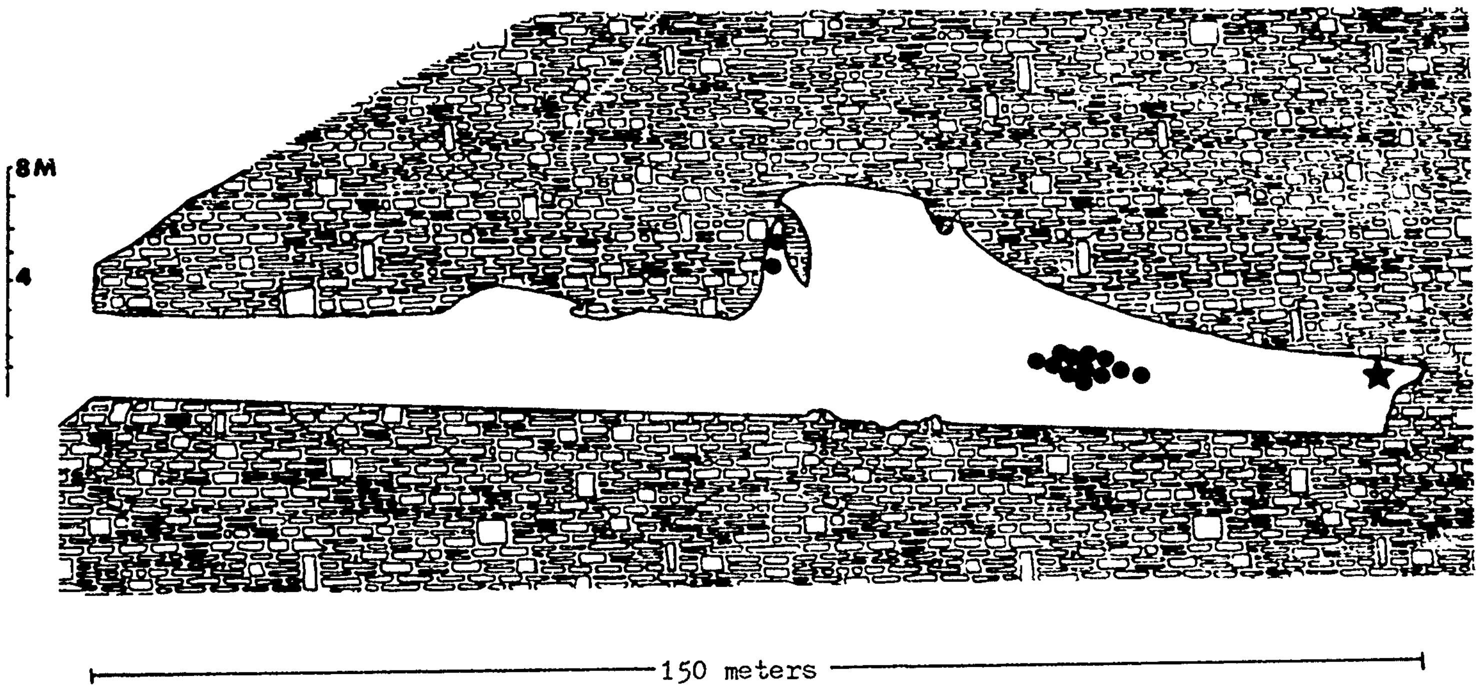


Fig. 13. Longitudinal section of cave 021. For interpretation of symbols see Fig. 11.

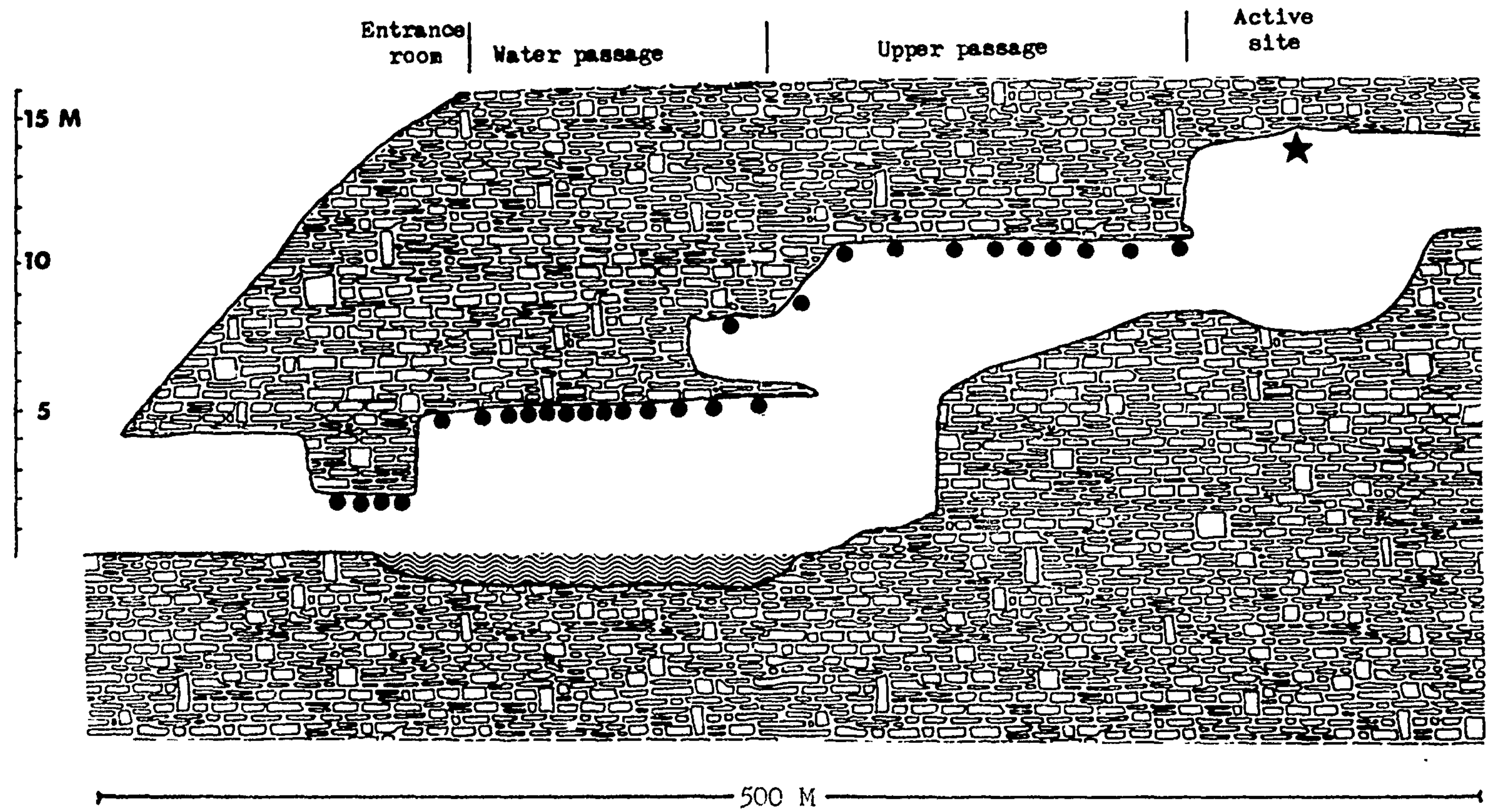


Fig. 14. Longitudinal section of cave 029. For interpretation of symbols see Fig. 11.

Table 21. Number of hibernating M. sodalis, mean cluster size, and environmental readings at cave 029, October 1975 - April 1976.

Cave Area	Month	Number of bats	Per-cent of total	Mean cluster	Rela-tive Humi-dity	T_{air}	T_{rock}	T_{bats}
Entrance Passage	October	0	0	0	-	-	-	-
" "	November	0	0	0	-	-	-	-
" "	December	1,930	4.97	321.60	80	9.4	9	-
" "	January	6,421	13.78	194.58	85	0.8	2	1
" "	March	1,462	3.86	58.48	74	9.6	8	8
" "	April	0	0	0	83	9.6	10	-
Water Passage	October	999	4.58	39.96	88	12.2	10	-
" "	November	19,567	53.45	52.88	91	12.8	12	-
" "	December	31,727	81.65	88.10	80	9.4	10	-
" "	January	32,838	70.46	98.02	82	2.8	6	5.5
" "	March	9,792	25.84	38.25	79	12.6	12	-
" "	April	5	0.35	1.00	85	10.6	-	-
Upper Passage	October	6,811	40.46	24.86	94	12.6	12	12
" "	November	8,059	22.02	6.83	91	12.1	-	-
" "	December	4,066	10.45	7.23	88	11.4	11	-
" "	January	7,305	15.67	11.80	82	10.0	10	-
" "	March	21,278	56.82	8.13	90	11.2	11	-
" "	April	884	61.60	-	88	11.2	-	-

Table 21. (Continued)

Cave Area	Month	Number of bats	Per-cent of total	Mean cluster	Rela-tive Humi-dity	T_{air}	T_{rock}	T_{bats}
Active site and deeper cave	October	11,942	54.96	34.77	94	12.8	12	12
" "	November	8,979	24.53	6.55	94	13.0	13	-
" "	December	1,136	2.92	1.73	90	12.3	11	-
" "	January	42	0.09	2.25	90	9.7	11	-
" "	March	5,108	13.48	4.92	94	12.0	11	11
" "	April	546	38.05	3.50	91	11.8	-	-

\- No reading.

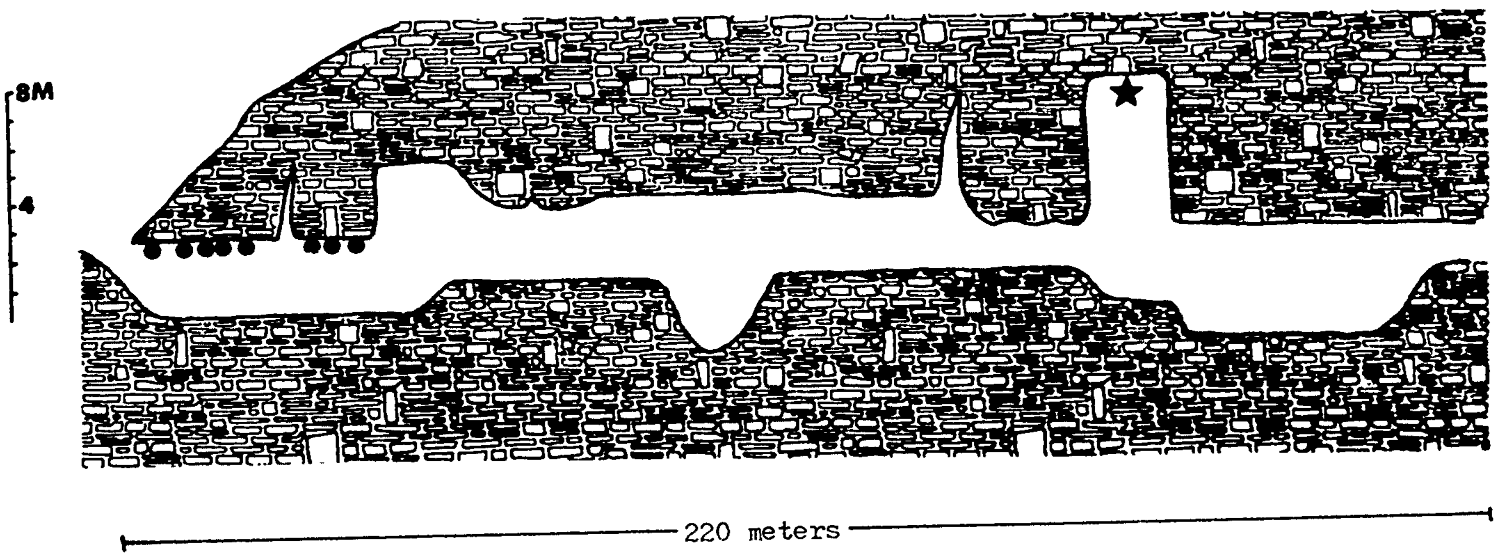


Fig. 15. Longitudinal section of cave 031. For interpretation of symbols see Fig. 11.

are near the entrance, and most are within easy reach of would-be vandals. However, during early winter, when cave temperatures are relatively uniform, bats tend to roost in less accessible inner passageways of caves, so that the most critical period is December-February, when bats have moved to the colder portions of the cave near the entrance. At this time clusters are significantly larger, (Clawson, _et al_., 1976), further increasing vulnerability to disturbance and vandalism. Comparison of Fig. 14 and Table 21 shows the relationships among temperature, mean cluster size, and distribution of bats in cave 029 during the winter of 1975/76. As can be seen in Table 21, early and late in the hibernation period the majority of the hibernating _M. sodalis_ (over 90 percent in October and April) were found in the upper, warmer portions of the cave, but in mid-winter, most of the bats (85 percent in December and January) were found on colder rock in the entrance and water passages. As is evident from Fig. 16, populations of hibernating _M. sodalis_ change appreciably from month to month during the winter, with the higher estimates from the November-March period. However, thousands of _M. sodalis_ are present in hibernacula from 20 October through 30 April (Hall, 1962; Hassel, 1967), so that efforts to protect the bats from disturbances must extend not only throughout that period, but must include a two-week buffer period before and after to protect early arrivals and late departing bats.

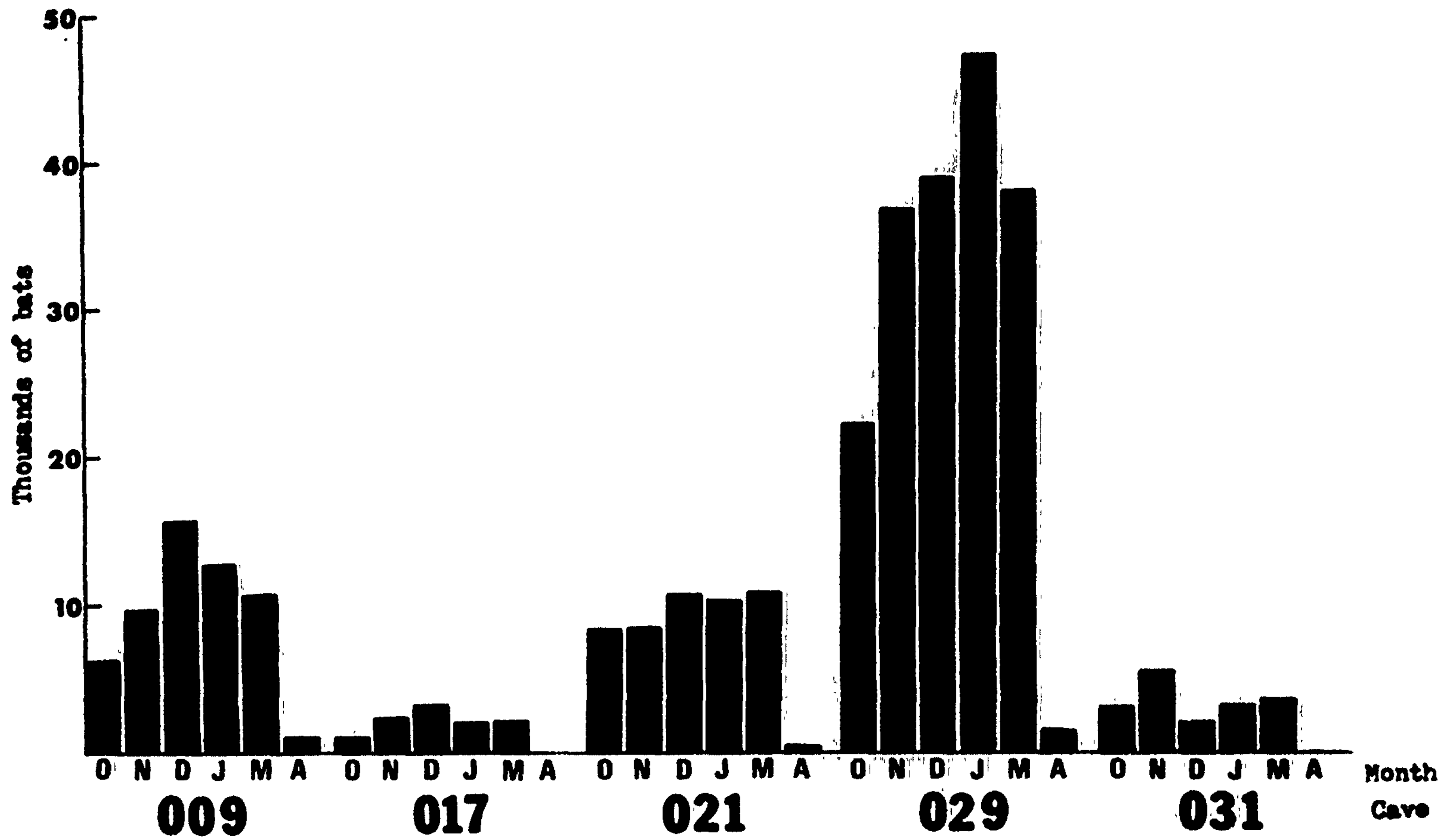


Fig.16. —Monthly variation in numbers of Myotis sodalis in five major hibernacula.

Myotis lucifugus

Myotis lucifugus hibernate individually or in small clusters. Individuals tend to be in the warmer, deep cave passages, while clusters tend to be in the cold zone, often adjacent to *M. sodalis* clusters. A mild stimulus such as the sound of footsteps under the roost, which would cause arousal in *M. sodalis* (Myers, 1975; Humphrey, 1977), seems to have little effect on *M. lucifugus*. Thus visitation to caves used by these bats causes less disturbance to *M. lucifugus* than to *M. sodalis*, assuming no overt attempt is made to molest the bats.

Myotis keenii

Myotis keenii apparently hibernate in crevices in caves (Barbour and Davis, 1969). They were sometimes seen in these situations in Meramec Lake area caves, but normally very few bats of this species were observed in caves, even on warm nights when sizable numbers were trapped at emergence. Such bats usually had mud or clay clinging to their fur, leading us to suspect that they crawled out of cracks or crevices. Therefore, we can say little about their environmental preferences in caves, except that we observed or trapped them at a number of caves where *M. sodalis* did not occur. One thing is clear: hibernating *M. keenii* are less likely to be subjected to disturbance than other species of myotine bats in our area.

Myotis grisescens

Myotis grisescens does not hibernate in the study area and was found in relatively low numbers as transients, primarily during October (4973) and April (11363) (Table 17).

Winter Recovery of Banded Bats

During October, early November, March, and April, bats entering and leaving hibernation were captured at cave entrances for banding, sexing, and weighing. During these months, some bats, mainly active *M. grisescens*, were captured inside the caves and banded. The following numbers of bats of each species were handled during Phase III (number banded in parentheses).

Myotis sodalis	5494	(3906)
Myotis grisescens	1960	(1499)
Myotis lucifugus	264	(243)
Myotis keenii	154	(114)
TOTALS	7872	(5762)

Because banding activities did not commence until August, relatively few (397) *M. sodalis* were banded during the summer of 1975. Of these August-banded bats, 52 were captured during Phase III. However, because hibernating bats were normally not disturbed any more than necessary, the band numbers of bats observed in torpor were rarely recorded. Thus it seems probable that a far greater number of the 397 August-banded individuals were actually present in the winter, because 1344 (47 percent) of the 2859 M. sodalis banded prior to hibernation in 1975 were observed during the January census. Due to the difficulty in seeing bands in tightly packed clusters (especially when on high ceilings as in some portions of cave 029) it seems possible that many were overlooked, and thus that most of the M. sodalis banded did indeed hibernate in Meramec Lake area caves. Other species were not banded in large enough numbers during August to expect many winter recaptures, except M. grisescens (N=298), which winters outside the area. Nearly 400 M. grisescens banded in Meramec Lake area caves were observed in two caves in Shannon County, Missouri, during the first week of March.

Phase V

Analysis of the Impact of Meramec Park Lake and Union Lake on Myotine Bats

For the purposes of this report, the significant impacts of Meramec Park Lake and Union Lake will include the following:

1. Destruction of foraging habitat by flooding, clearing, development, or pollution.

2. Destruction of roosting or hibernating caves by flooding, pollution, or other alterations.

3. Disturbance of roosting, hibernating, or foraging bats by human activity.

That destruction of foraging habitat and caves used by bats will have a profound negative impact on their populations cannot be contested. See, for example, Humphrey (1976; 1977), Humphrey and Cope (1976), Tuttle (1976), Mohr (1972) and Jones (1971). Likewise, disturbance of bats, especially while roosting or hibernating in caves, can result in unsustainable mortality levels (see Humphrey, 1977; Tuttle, 1976).

The _M. sodalis_ population decline between March 1975 and March 1976 in the Meramec Park Lake area has been amply documented by Humphrey (1976) and has been observed repeatedly in this study. Humphrey (1976) stated that: "Between March 1975 and March 1976 the four hibernacula ... have declined from 118750 to 61569 Indiana bats, a loss of 48.2 percent." "The known rate of cave visitation is suspected to be high enough to have caused the declines."

At the five _M. sodalis_ hibernacula we attempted to estimate the actual number of visits that occurred during the 1975-76 hibernating season as follows:

Cave no. 009 - 6 visits

Cave no. 017 - 17 visits

Cave no. 021 - 10 visits

Cave no. 029 - 10 visits

Cave no. 031 - 8 visits

These totals include visits made by our research group. They should be considered as conservative figures, as it would easily be possible for visitations to occur without our knowledge. Humphrey (1977) concluded that the maximum tolerable visitation rate to *M. sodalis* hibernacula is one per year.

The estimated relative severity of destruction or disturbance to myotine bats in the Meramec Park Lake area is summarized in Tables 22, 23 and 24. Destruction or disturbance judged to be minimal (L) or moderate (M) would probably have a very limited impact during any one phase of the development in the project area. However, in combination these minor impacts would have a more serious impact, albeit one difficult to assess.

Table 25 presents Corps projections of lake elevation probability and frequency of occurrence. This table, used in conjunction with Tables 16-19 and 23, allows one to make rough predictions as to relative probability of the different bat caves and populations being inundated. It must be remembered, however, that regardless of the projected frequency, one flood of great magnitude could drown the bats in affected caves.

Myotis sodalis

The impacts judged to be very severe (S) in Tables 22 and 23 will be dealt with in detail. In the case of *M. sodalis*, filling of the lake to normal pool will flood at least four caves used by this species (Tables 16, 22, and 23). None of these caves

Table 22. Negative impacts of Meramec Park Lake on myotine bats.

	Myotis sodalis			*Myotis grisescens*			*Myotis lucifugus*			*Myotis keenii*			
	Destruction of foraging habitat	Destruction of caves	Destruction of roosting, hibernating, or foraging bats	Destruction of foraging habitat	Destruction of caves	Destruction of roosting, hibernating, or foraging bats	Destruction of foraging habitat	Destruction of caves	Destruction of roosting, hibernating, or foraging bats	Destruction of foraging habitat	Destruction of caves	Destruction of roosting, hibernating, or foraging bats	Overall impact
Dam construction	L	N	N	L	M	L	N	N	N	N	N	N	L
Buildings, structures and facilities	L	N	N	N	N	N	N	N	N	L	N	N	L
New and relocated roads	L	N	N	N	N	N	N	N	N	N	N	N	L
Filling of the lake to normal pool	M	M	S	U	S	S	L	M	M	L	S	L	S
Filling of the lake to flood pool	M	M	S	U	S	S	L	S	S	L	S	L	S
Operation of the lake	N	N	L	N	N	M	N	N	N	N	N	N	L
CE developments (intensive use areas, etc.)	M	L	L	L	S	S	U	L	L	M	L	L	S
Private developments	M	L	L	M	M	M	U	L	L	M	L	L	U
Increased human disturbance	U	S	S	U	S	S	U	S	S	U	S	U	S

L minimal destruction or disturbance
M moderate destruction or disturbance
S very severe destruction or disturbance
N no destruction or disturbance
U effect unknown or unclear

Table 23. Anticipated impacts of the proposed Meramec Park and Union lakes on caves currently utilized by endangered species of bats. Relative importance to the two non-endangered myotine species is also shown. If adequate protective measures are taken, impacts on some of the caves may be lessened.*

Cave	Important to: *M. sodalis*	*M. grisescens*	*M. lucifugus*	*M. keenii*	Impacts: Permanently flooded (normal pool)	Occasionally flooded (flood pool)	Groundwater hydrology change	Increased visitation	Nearby development	Pollution of groundwater	Overall severity of impact
006[1]			X	X				M			M
009	X	X	X	X				L			L
013	X		X		D						D
017	X	X	X	X				S			S
021[2]	X	X	X				U	S	U	U	U
022	?		X	X		S	S	S	U	U	S
023		X			D						D
029	X	X	X	X				S	U	U	S
030	?	X			D						D
031	X		X					M	U		M
034		X						M	U		M
035		X						M	U		M
036		X						L			L
039		X				D	S	S	S	U	D
044		X				S	S	M	U	U	S
048		X						S	U		S
049		X						S	U		S
054		X						S	U		S
058		?						S	U		S

L little impact
M moderate impact
S severe impact
D absolute destruction
U impact unknown or could not be determined by us

[1] Visitation to commercial caves is expected to increase due to the influx of more people and the loss of Onondaga Cave.

[2] Unknowns such as potential hydrological changes and nearby development cloud the picture at cave 021.

* The numbers of bats which will be affected by changes in these caves is indicated in Table 24.

Table 24. Greatest number of bats observed or handled in any one day during the period 1 August 1975 through October 1976 at each of the caves currently utilized by these bats.

Cave	*Myotis sodalis*	*Myotis grisescens*	*Myotis lucifugus*	*Myotis keenii*
006	2	1	48	162
009	15,528	500	131	91
013	122	0	24	1
017	2,974	600	312	35
021	10,787	768	102	2
022	41	9	198	45
023	3	500	6	0
029	46,606	5,012	111	467
030	38	7,350	8	8
031	5,483	0	253	3
034	0	1,350	0	0
035	1	700	3	0
036	1	20,000	0	0
039	5	6,783	10	17
044	15	1,368	14	4
048	0	9,600	0	0
049	0	9,410	0	0
054	0	* 7,200	0	4
058	8	** 8	17	0
	81,614	71,159	1,237	839

* 3600 juveniles were observed at night while the adults were out foraging. Thus the total number of bats (juveniles and adults) must have been at least double the amount of juveniles observed, as females have one young per year.

** Dr. R. Coles of Washington University observed approximately 1000 in this cave in early November 1976.

Table 25. Projected probability of occurrence, frequency of occurrence, and percent of time at or above a given elevation for different pool elevations of the Meramec Park Lake. The source of data is Plate 3 of Design Memorandum # 9, the Master Plan (anon., 1976).

Pool Elevation	Probability of occurrence in percent	Frequency of occurrence in years	Percent of time at or above elev.
675	87	1	80
680	58	1.8	3
685	25	4	1.4
690	5	20	.45
695	.2±	150±	.07
700	.001±	300±	.01±
705		Not measurable	
709		Not measurable	

are major hibernacula, but one of them (013) offers excellent microenvironmental conditions for hibernation and may have hosted much larger populations in the past. At maximum flood pool, two additional caves used by *M. sodalis* would be flooded, one of them a swarming cave (022). Furthermore, filling of the lake would destroy a very substantial amount of the flood plain forest and part of the hillside forests now used in foraging activities, although the ridgetop forest and much of the hillside forest will remain intact. Because many roosting caves will be near the lake, much of the nearby foraging habitat will be flooded and we are convinced that bats will be forced to fly greater distances to forage with comcomitant extra energy expenditure. Furthermore, if summer *M. sodalis* roost sites are located in flood plain trees as in Indiana (Humphrey, *et al.*, 1976), then these sites will no longer exist, as all riparian and flood plain vegetation in the normal pool area will either be cut or flooded. As previously noted, *M. sodalis* females are apparently not present in the study area during the maternity season. Although we could catch sizable numbers of *M. sodalis* males in cave entrances, we did not observe comparable numbers roosting in the caves; we therefore suggest that these bats may be roosting in trees. And, since we know that females roost in flood plain trees in Indiana, it is not unreasonable to expect that some or all of the *M. sodalis* in the study area roost in flood plain trees in the summer.

Perhaps most critical is the proximity of the lakeshore to caves used by M. sodalis (especially 021, 022, and 031), allowing relatively easy access to these caves by persons in motorboats. Even though 021 has been gated, visitors to the entrance could still disturb the hibernating bats that are just beyond the twilight zone by firing weapons, exploding fireworks, etc., or simply by rattling the gate. Few caves will be safe from disturbance when visitation reaches the projected level of four million visitors to the Meramec Park Lake area in 1990, as predicted in the Master Plan (anon., 1976).

In summary, activities associated with the construction and development of the Meramec Park Lake, and the filling of the lake itself, will leave much of the foraging habitat and all of the currently used major hibernacula intact. However, serious disturbance of hibernacula and other caves used by M. sodalis seems inevitable unless stringent precautions are taken such as gates and fences to keep people out of and away from important caves.

Myotis grisescens

In contrast with M. sodalis, impacts on M. grisescens will be much more serious (Tables 17, 22, 23 and 24). Filling of the lake to normal pool will flood cave 030. This cave contained 7350 M. grisescens in September 1976, and may have been a major maternity cave prior to recent disturbance. Cave 023, also in the normal pool, harbored 500 bats in October of both 1975 and 1976, and it is likely that many more bats have used this frequently disturbed cave in the past. The flood pool would inundate cave 039 approximately every 3 years (see Table 25). This cave has contained nearly 7000 bats (and perhaps thousands more, owing to difficulty in estimating numbers at this cave), including a small group of females with nursing young. Cave 044, also in the flood pool, has held nearly 1400 bats by our count, and perhaps as many as 15000, according to St. Louis University biologist David Bechler, who visited the cave in October 1975, before we were aware of its existence. In short, of the approximately 50000 _M. grisescens_ in the project area, at least 15000, and perhaps as many as 30000, use the four caves that will be flooded. Of these four caves, 030 is probably of critical importance to the species, because females from three of the four maternity caves congregate at this cave prior to migration in September. At various times of the year, thousands of males and juveniles also gather there. Cave 039 is the major summer roost for adult males in the area. Among other caves in the project area used by _M. grisescens_, none seems to be ideally suited for absorbing populations forced to vacate these two caves should they be sealed prior to filling the lake. Should the caves not be sealed prior to filling the lake, the probability of drowning the bats therein is quite high.

All the other caves used by *M. grisescens* (except 036), although above flood pool or downstream from the dam, are close enough to the lake to suffer from human disturbance when peak visitation occurs. The amount of disturbance each cave is subjected to varies, but the presence of spent rifle cartridges, beer bottles, and other refuse attests to the seriousness of the problem now, and it can only worsen if the lake is constructed. Increased canoeing downstream from the dam due to the loss of 50-67 miles (80-108 km) of float stream will seriously jeopardize cave 054. There seems to be little question that construction of Meramec Park Lake will result in a serious fragmentation of cave populations of *M. grisescens*, and probably in a precipitous population decline in the lake area. M. D. Tuttle (*in litt.*) and R. F. Myers (*in litt.*) have witnessed such *M. grisescens* population fragmentation and decline near TVA reservoirs and the Lake of the Ozarks, respectively.

As we have shown in this report, based on our stream netting and light tracking, *M. grisescens* forage almost exclusively over rivers and streams adjacent to riparian vegetation. We think that most of the maternity population of 15000 *M. grisescens* at cave 036 forages in areas not impacted by Meramec Park Lake. The remaining 35000 regarded as the summer population of the lake area presently depend on 297 km of permanently flowing streams and river for foraging habitat. One hund: ed and ten kilometers of this habitat will be destroyed by normal pool, and up to 69 km more will be inundated by flood pool. This loss will amount to 179 km (60 percent) of the calculated summer foraging habitat of _M. grisescens_ (based on a 17 km foraging range, the maximum observed in this study) using caves along the Meramec in the vicinity of Meramec Park Lake. According to M. D. Tuttle (pers. comm.), reservoirs built by the Tennessee Valley Authority in eastern Tennessee are used by foraging _M. grisescens_, but one cannot conclude from this observation that Ozark reservoirs, particularly the Meramec Park Lake, will constitute acceptable and adequate foraging habitat. In fact, Tuttle does not maintain that reservoirs provide superior, or even equal foraging habitat.

In summary, activities associated with the construction and development of Meramec Park Lake, and the filling of the lake itself, will destroy or adversely affect four roosting caves used by as many as one half of the _M. grisescens_ in the area. In addition, 60 percent of the foraging habitat used by the _M. grisescens_ in the area will be destroyed. However, it will be replaced by habitat that, though both quantitatively and qualitatively different from the original, may possibly prove to be acceptable to those bats that remain in the area; unfortunately we have no evidence to indicate that this is in fact the case. An intriguing question, one for which we have no answer at present, concerns changes in insect fauna associated with the change in aquatic environment. Would a transition period from insects associated with deep lake water result in an interval of low insect abundance? If so, this period might be very damaging to M. grisescens populations.

Myotis lucifugus

The impacts of Meramec Park Lake on M. lucifugus are difficult to assess because of the difficulty in obtaining adequate data on the species here. Scanty foraging data suggest that this species forages in a variety of habitats, some of which would be inundated by the lake. The most serious impacts arise from the flooding of hibernacula. Bats of this species are spread out among many caves in winter; among those caves in normal or flood pool, eight serve as hibernacula for M. lucifugus (Table 18). Of these, cave 022 (flood pool) contained 22 percent (N=198) of all hibernating M. lucifugus observed during January 1976. This particular cave is popular with cave explorers, and increased visitation (and thus increased disturbance) could be expected following filling of the lake. Caves 021 and 031, which together account for nearly one half of the hibernating M. lucifugus observed in December 1975, are both above the flood pool but near the lake, and increased visitation and disturbance can be expected.

In summary, activities associated with the construction and development of the Meramec Park Lake, and the filling of the lake itself, will adversely affect portions of the foraging habitat of *M. lucifugus*, and will flood at least eight caves used by the species (Tables 18 and 22). Several other caves used as hibernacula will probably be subjected to increased disturbance.

Myotis keenii

As in the case of *M. lucifugus*, the impacts of Meramec Park Lake on *M. keenii* are difficult to assess. It appears that *M. keenii* forage in dense forest along hillsides and ridges, much of which will remain intact. However, it seems evident that development of the lake area, both on government and private land, will result in clearing and partial clearing of portions of the foraging habitat of *M. keenii*. *M. keenii* roost in small numbers spread among a large number of caves in the area (Table 19). Filling of the reservoir will probably destroy 25 to 50 percent of their roosting habitat, and, if waters rise during the period of hibernation, large numbers will probably be drowned. Because the hibernating sites of *M. keenii* are cryptic, we were able to obtain data only at trapable caves. Thus, very large caves in the normal pool, such as 013 and 015 that were untrapable, may contain sizable populations of *M. keenii* undetected by us.

In summary, activities associated with the construction and development of the Meramec Park Lake, and the filling of the lake itself, will adversely affect portions of the foraging habitat of M. keenii. More importantly, a large number of caves utilized or believed to be utilized by this species will be flooded. Furthermore, if these bats roost under the bark of riparian trees, as in Indiana (Mumford and Cope, 1964), then the lake will destroy much of their summer roosting habitat (Table 22).

In general, we believe that any alteration or destruction of existing habitat resulting from construction of Meramec Park Lake and ensuing public and private development will have a serious negative impact on myotine bats resident in the area, although the impact can hopefully be reduced by wise planning and management. Caves used by roosting bats are especially vulnerable to damage by human activities, including not only physical disturbance of the bats, but alteration of cave microclimates by construction of gates, walls, and other structures at cave entrances, or by allowing untreated sewage or other wastes to enter cave watersheds. The latter effect can be especially insidious, and if it is to be avoided, careful monitoring of all development schemes is required.

Union Lake

The foregoing discussion was intended to apply specifically to Meramec Park Lake. Many of the comments relating to foraging habitat apply equally to the proposed Union Lake. We suspect that the present population density of bats is lower in the Union Lake area due to large scale clearing for agriculture, limiting available foraging habitat. Development of a reservoir for public use would probably result in further depletion of foraging habitat.

In spite of this, impacts of the proposed Union Lake are substantially less than for the Meramec Park Lake, simply because the Union Lake area contains few caves. Most of those few are unsuitable for bats. The only significant bat caves are caves 048 and 049; cave 048 is a large maternity roost for M. grisescens, and 049 is used as an alternate roost, probably by the same bats. Fortunately, these caves are downstream from the damsite. However, because of their proximity to the dam (two airline miles), a substantial amount of disturbance could be expected. As these are the only M. grisescens roosts known to us along the Bourbeuse River, serious disturbance leading to abandonment of these caves could have a disastrous impact on the population in that area. Because the populations of the two rivers exchange freely, and most of the bats from cave 048 swarm at cave 030 on the Meramec, construction of either dam would have an impact on bats using the other river area, and a maximum impact would result from construction of both dams.

Climate

In this section we have made no mention of the possible effects of the two lakes on local climate, which in turn might affect habitat used by bats. According to Charles Thornton, Southern Illinois University climatologist, there is no hard data relating to the effects of Ozark reservoirs on the local climate. However, based on his personal experience, a reservoir of the size and width of Meramec Park Lake will have a very negligible effect on the climate. James McQuigg, formerly of the Department of Atmospheric Sciences, University of Missouri, suggested that any temperature modifications resulting from the presence of the lake would be restricted to within a few feet of the lake's edge. Therefore we judge that any impact on the bats from this source would be slight or nil.

Phase VI

Species Management

The management of wildlife, primarily those species of interest to hunters and fishermen, is a long-established practice and tradition in the United States. When sound ecolrgical principles have been applied, management has generally been effective. To the best of our knowledge, there have been no prior efforts in the United States at management of populations of bats, but there seems to be no reason why such efforts should not succeed. Basically, wildlife management involves:

1) the regulation of legitimate harvest, poaching, vandalism, and other practices that might result in unsustainable levels of mortality if not controlled, 2) the protection of existing habitat critical to the survival and reproduction of the species, and 3) the manipulation of habitat to enhance its value and thus to insure survival and reproduction of the species. Depending on the circumstances, it may be necessary to implement all three, two, or only one of these management practices.

It is axiomatic that endangered species require some form of management, as, by definition, most of them would become extinct otherwise. The reason such species are endangered is man's history of habitat mismanagement. Projects such as the proposed reservoirs constitute exactly this sort of mismanagement. The Endangered Species Act of 1973 requires governmental agencies to take such measures as are necessary to protect and manage endangered species. The mechanism established by the Act and the U.S. Fish and Wildlife Service to develop management options is the Recovery Team, one of which has been established for _M. sodalis_, but not for _M. grisescens_ (which was only recently added to the endangered species list). The Recovery Team gathers data on the status of the species, and in consultation with qualified biologists who have carried out research on the species, formulates a plan designed to lead to recovery of the species and ultimate removal from endangered status. A preliminary Recovery Plan (Engel, *et al.*, 1976) has been tenatively approved by the U. S. Fish and Wildlife Service, but will be revised shortly. Nevertheless, the stipulations of the plan with regard to protecting winter habitat are quite explicit and should be reviewed by readers of this report. Most of the caves recommended for special protection in the Recovery Plan have in fact been designated as "Critical Habitat" in the Federal Register, under the provisions of the Endangered Species Act. Four of these caves are in the vicinity of Meramec Park Lake: caves 009, 017, 021, and 029. The Army Corps of Engineers and other government agencies operating in and near the Meramec Park Lake project area are therefore responsible for protection of these caves and the bats therein. Caves 009 and 017 are owned by the state of Missouri; cave 021 is on land purchased by the Corps of Engineers for the Meramec Park Lake; cave 029 is on private property, but will be impacted by increased visitor use if the dam is constructed.

There are no basic conflicts between humans and bats in the Meramec Basin. The bats help control noxious insects, and ask in return only to be left alone. The combination of extensive areas of forest and numerous permanent rivers and streams with a large variety and number of caves makes this area of unique value to myotine bats, especially the endangered species *M. sodalis* and *M. grisescens*. If the bat caves had not been molested by people, either intentionally or unintentionally, drastic population declines could probably have been avoided up to this time. Any management decisions made (if the Meramec Park Lake was not a factor) would reflect the fact that currently existing habitat is probably quite adequate, if only caves used by bats could be protected from human disturbance. Thus, it would be necessary to exercise only the first two wildlife management options, except that the construction of Meramec Park Lake complicates the situation considerably. The lake would destroy significant foraging and roosting habitat, thus necessitating application of the third management option.

The most obvious and most effective single step that could be taken to help prevent further decline in populations of the endangered *Myotis sodalis* and *Myotis grisescens* in the Meramec Park Lake project area is for the Corps to cease construction on the dam and for the Congress to de-authorize the project. However, whether or not the lake is constructed, caves used by the endangered bats must be protected from human disturbance, as outlined in the following paragraphs.

Myotis sodalis

If populations of *M. sodalis* are to recover, with or without Meramec Park Lake, the five hibernacula must become inviolate. (Recommendations for management of these and other caves are contained in Table 26.) Bats hibernating in caves

Table 26. Recommendations for management of important bat caves in the Meramec Park Lake area.

Cave	Gating	Fencing	Purchase	Restoration
006	X			X
008				X
009	X	?		
017	X	?		
021	X			
022*				
029	X		X	
031	X	?	X	
034			X	
035			X	
036			X	
044*			X	
048		?	X	
049			X	
054		?	X	
058	X	X	X	X
C1				X

* Management options are limited because of the danger of periodic flooding.

009, 017, 021, 029, and 031 must be protected from human disturbance regardless of cost. Gates constructed of welded steel bars and set in rock or concrete seem to be the most effective means of restricting human entry to the caves. Such a gate has already been constructed at cave 021 by the U. S. Army Corps of Engineers. An improperly designed gate might defeat its own purpose by denying access to the cave by bats. The gate at cave 021 was designed following our recommendations, plus those of S. R. Humphrey and R. F. Myers. Observations made in September 1976 at night with a night viewing device indicate that M. sodalis will fly through the gate without hesitation. We therefore recommend urgently that similar gates be constructed at the remaining hibernacula. Because of the alarming rate of population decline observed between 1975 and 1976 (Humphrey, 1976), we emphasize that the gates should be constructed without delay.

Even though a gate is in place, development (either public or private) must be kept well away from the entrances to the hibernacula because M. sodalis clusters are frequently located near the entrance where human-related noise could easily result in disturbance. The placement of appropriately worded interpretive signs inside the gates should serve to placate would-be spelunkers, especially if the sign announces that the gate will be open during a portion of the year. The placement and wording of such signs should be determined in coordination with the U. S. Fish and Wildlife Service and the Missouri

Department of Conservation. However, while the bats are hibernating (1 October-1 May) no person should be allowed to enter the cave, except qualified scientists operating under Endangered Species permits, and these visits should be limited to once every year or two for census purposes. In fact, census visits should be arranged by the government and scheduled at two-year intervals.

Furthermore, development in the watershed of a hibernaculum that might result in pollution of groundwater by sewage or chemicals must be avoided. Two of the hibernacula contain flowing streams, and two contain transient lakes. We recommend that a competent ground water hydrologist be consulted to determine what dangers might be inherent in contamination of cave watersheds. We believe, however, that as long as development is kept well away from these watersheds, and they remain in forest, little danger from this source exists. The Corps should take whatever steps are required to protect these watersheds.

Cave 009, a remote sinkhole cave on state land, would be quite secure if gated or fenced as it contains little of interest to spelunkers and is infrequently visited. The cave gate could be left open between 1 May and 1 October. M. D. Tuttle (_in litt_.) suggested that caves such as 009 that are of little interest to spelunkers could be locked year-round. He further suggested that caves with small entrances should be fenced rather than gated because of the danger from predators waiting where the gate forces the bats to swerve and fly slowly. It seems to us that there is also the possibility that leaves, fallen limbs and other litter might block the entrance to a cave at the bottom of a sinkhole. If fences are constructed instead of gates they should be located at least 20 feet from the cave entrance so as not to impede bat flight. An old, overgrown road leading to within 100 m of cave 009 should be permanently closed.

Cave 017, also on state land, has a small sinkhole entrance located adjacent to a paved road; it is frequently visited by spelunkers, boy scouts, local teenagers, and state park visitors, among others. It should be gated or fenced, with the gate left open from 1 May to 1 October, but must be examined frequently for gate vandalism during the hibernating season.

Cave 021, gated during August 1976, will be relatively close to the edge of the lake. Because this cave is used by _M. grisescens_ in the summer and _M. sodalis_ in the winter, it should be kept locked year-round, unless subsequent monitoring activity at the cave reveals that _M. grisescens_ will not pass through the locked gate. Should that be the case the gate could be open from 1 May to 1 October. The cave should be off limits to Meramec Park Lake visitors when locked, and protected by lake rangers in boats. A small strip of the privately-owned land above cave 021 should be purchased by the government to prevent development and forestall possible sources of disturbance and degradation of the cave watershed.

Cave 029, a cave with a large entrance on private land, is the single most important bat cave in the project area. This extensive cave, with its entrance less than one mile from state highway 185, is very popular with spelunkers. In addition to being one of the largest M. sodalis hibernacula remaining in existence, it supports a transient colony of male M. grisescens numbering up to 5000. It should be gated and locked year-round.

Cave 031, an extensive cave with a sinkhole entrance on private land, is fairly remote at present, but will be within a mile of the edge of the lake. It will undoubtedly be subjected to increased visitation after the lake is filled. It should be gated or fenced, with the gate open from 1 May to 1 October.

Another approach to cave management with respect to M. sodalis would be the restoration of caves that are currently sealed or heavily disturbed. Mr. Lester Dill, owner of Meramec Caverns and Onondaga Cave, reported to us that large clusters of bats (probably M. sodalis) formerly hibernated in Onondaga Cave, Cathedral Cave, and cave 006. All of these caves are now commercialized. Cave W5 (MSS number), located adjacent to a private campground and thus frequently disturbed, was reported by local residents to have contained large wintering clusters (M. sodalis?) at one time. These caves could be restored by removing improperly designed gates and other obstructions, as well as lights, sidewalks, and other developments, at least from the bat use areas. They could then be protected by installing gates of approved design. Cave 058, on private property, appears to offer ideal hibernating conditions for M. sodalis. Its management is discussed under M. grisescens.

Myotis grisescens

Among the four species of myotine bats in this area, only M. grisescens roost exclusively in caves during the spring, summer and autumn, and only M. grisescens raise their young in caves (Tuttle, 1976b). Because these bats also hibernate in caves (outside the project area), their entire life cycle depends on the presence of suitable subterranean habitat. Unlike M. sodalis, they utilize numerous caves as various kinds of roosts. Fourteen such caves are located in the Meramec area, including two on the Bourbeuse River,(Table 26).

Myotis grisescens are highly susceptible to disturbance, especially at maternity colonies (see Tuttle, 1975). Although positive measures are necessary to protect the caves, it is unclear at present if bats of this species will fly through a gate. We found a cluster of M. grisescens inside cave 021 just a few days after erection of the gate in late August 1976, but few were present during the ensuing weeks. M.D. Tuttle

(1976a and pers. comm.) recommends against gating *M. grisescens* caves. Investigations currently underway by M. J. Harvey, Memphis State University, at a large, recently gated *M. grisescens* cave in Arkansas may soon give us meaningful data relating to this problem.

Should it ultimately be decided that gates of the current design cannot be used, there are various alternatives, including some modification of the existing design; an abbreviated gate that stops short of the ceiling; a heavy barbed wire/chain link fence, set in concrete, some distance from the cave entrance. Any type of device that might prevent or discourage visitation could be used, as long as it would have no disturbing effects on the bats inside the cave.

Other previous comments regarding the protection of cave watersheds, nearby development and visitation, and erection of interpretive signs for hibernacula apply as well to *M. grisescens* caves. In general, gated or fenced *M. grisescens* caves should be closed from 15 March to 1 November.

Cave and management recommendations are grouped below in categories based on relation to the height of normal and flood pools, or up and downstream from the lake.

Three caves are located in the normal pool and thus will be flooded. Cave 015 is used by relatively small numbers of transient *M. grisescens*, which, if present when the lake level rises, could escape easily. Cave 023 is used by somewhat greater numbers of transients. Although rising waters might trap some of these bats, it seems unlikely to us. Cave 030 is used by more _M. grisescens_ than any other non-maternity cave in the area, up to 9000 at once, and probably by more than half the project area population during the course of a year. The passage leading to the bat chamber contains a narrow crawlway that could easily be blocked by rising waters, thus trapping thousands of bats. The cave must be sealed during the winter prior to filling the lake, when the _M. grisescens_ are absent from the cave. At that time, a biologist should be asked to capture all hibernating bats of other species in the cave for transport to another suitable hibernaculum. However, we recognize that long-term results from such a relocation may be poor (see Mohr, 1942).

Two caves are located in the flood pool. These are 039 (683 ft) and 044 (693 ft). Cave 039 is the most important summer male roost in the project area, and 044 is a transient roost that may briefly host a significant segment of the population. Floods such as those of 1927, 1935, 1945, and 1957 (anon., 1976) would inundate these two caves. In fact, according to Corps' calculations (Fig. 25), cave 039 would be flooded every three years. Most floods occur during June, a time when thousands of bats are present in cave 039. The bats must all fly through an opening about one foot high and two feet wide (.3 m x .6 m), and would be trapped if flood waters rose suddenly. Bats at cave 044 could be trapped in a similar manner, but are unlikely to be present in June. We recommend sealing cave 039 with the same qualifications as made for cave 030. Based on our data, it would not be necessary at present to take measures to protect cave 044. Should bats from one of the flooded caves move to 044, and remain there during periods of high flood frequency, then the cave would require protection. This cave, incidentally, is on private land.

Two caves, 034 and 054, are on private property below the dam. Both of these caves are on the Meramec River and subject to frequent disturbance by boaters. Cave 034 is a summer male roost and transient roost used by relatively few bats, and probably does not warrant protection at present, beyond erection of a warning sign. Cave 054 is a major maternity roost and must be protected by a gate or fence if it is to remain a viable site for raising young.

One cave, 021, is located on federal property just above flood pool. This cave is used by relatively small numbers of *M. grisescens*, mostly males and transients. Assuming the bats will traverse the gate now in place, they will be adequately protected. Because this is a cold cave, we do not anticipate that bats displaced from flooded caves will move there, based on our knowledge that most _M. grisescens_ prefer warm caves in the summer.

Four caves, 029, 032, 035, and 036, are located above flood pool on private property. Cave 029 is a major summer male and transient roost that will probably be gated to protect its large _M. sodalis_ population. Modifications in the current gate design may be necessary if it is determined that _M. grisescens_ will avoid such a gate. Cave 032 is a small summer male and transient colony that is, at present, adequately protected by the dairy farmer who owns the cave. Cave 035 is a small transient roost, the entrance of which is not visible from the river; it probably does not require active protective measures at this time. Cave 036 contains the largest maternity and transient populations of any cave in the project area. Fortunately, it is well away from the lake, and on a section of the Meramec rarely floated by canoeists. In the case of the latter three privately owned caves, the owners should be informed of their caves' importance and asked to discourage visitation.

Two caves, 048 and 049, are located two airline miles (3.2 km) downstream from the proposed Union Dam, on private property. Because cave 048 is a major maternity cave and has been subjected to severe disturbance, it should be gated, fenced, or otherwise protected. Cave 049 serves, perhaps, as an alternate roost for the bats from cave 048, and should be protected if the Union Dam is constructed, as visitation would no doubt increase. As with other privately owned caves, owners should be informed of their caves' importance and requested to discourage visitation.

As is the case with _M. sodalis_, we recommend that caves formerly used by _M. grisescens_ be restored to that use. These caves were easily detected by us during our investigations, as they contain piles of bat guano in various stages of decay. Only _M. grisescens_ deposits these guano mounds, at least in Missouri. Caves 006, 008, 058, F15, and Onondaga all contain sizable guano deposits but are not currently used by _M. grisescens_. Cave 006 contains an estimated 60 square meters of guano, suggesting that it once contained a _M. grisescens_ colony of a size far in excess of any existing in the Meramec Basin today. The colony was still extant in 1930, according to Lester Dill, original developer of the cave, but the bats abandoned the cave shortly afterward. Hopefully, the bats would return if the present gate were replaced with an appropriately-designed structure, and the public was excluded from this commercial cave. Cave 008 contained a rather large colony at one time, but bats are presently excluded by a concrete block gate. The gate should be replaced. Cave 058 probably contained a fairly large colony, now largely excluded by a chain link fence gate. However, a cluster of approximately 1000 M. grisescens was observed in the cave by personnel of the Tyson Valley Lab, Washington University, St. Louis, in November 1976. The two entrances should be gated (lower entrance) and fenced (the huge upper entrance) to prevent visitation from the adjacent campground.

Cave F15 contains small guano piles only. The bats probably abondoned the cave a number of years ago when it was subjected to quarry operations for removal of onyx. Protective measures are probably unnecessary, unless future monitoring studies establish that the bats have returned. Onondaga Cave contained a major colony, in the ceiling of the "Great Dome" in the "Big Room". Most of these apparently left in the 1930's, according to owner Lester Dill. In any case, all would have departed after 1945, when electric lights were installed. Even if the cave were partially flooded by the lake, it is probable that it could be restored to M. grisescens use, if people and development were excluded, and a gated opening made available for bat use.

Restoration of the above caves prior to the filling of the lake might provide shelter for colonies displaced by flooding of caves presently being used.

Myotis keenii and *Myotis lucifugus*

Because these two species are not currently on the national endangered species list, there are no legal obligations under the Federal Endangered Species Act to protect them or their habitat, although *M. keenii* is designated as rare on the official Rare and Endangered Species List of the state of Missouri, published in August, 1976. Nevertheless, the U. S. Army Corps of Engineers has stated their desire to "...assure the continuation of all myotine bat species in the project area" in the contract that authorized this study.

If effective steps are taken to protect caves used by *M. sodalis* and M. *grisescens*, much of the roosting habitat of *M. keenii* and *M. lucifugus* will also be safeguarded (Table 26). Cave 022 should also be protected, as it contained more than one-quarter of the hibernating *M. lucifugus* we observed during the winter of 1975-76, and also serves as an *M. sodalis* swarming site.

Foraging Habitat

The management of foraging habitat for the benefit of myotine bats is primarily a matter of preserving as much of the existing forest as possible. It is inevitable that development, both public and private, will result in some clearing of forest habitat. However, this can be minimized by clearing only those trees that stand in the way of structures. Meanwhile, some of the pastures on government land above normal pool can be allowed to undergo natural succession, resulting in the growth of new forest habitat, while others are managed to maintain them in an early stage of succession. Planning agencies in the surrounding counties should be encouraged to attempt to control any private developments that might result in large-scale clearing. Furthermore, all riparian habitat above normal pool should be preserved, if at all possible. These actions will alleviate to some extent the loss of forest habitat due to flooding by the lake and help maintain the degree of habitat diversity which is responsible for the species diversity and abundance typical of the Meramec Park Lake area.

Compensation for Habitat Loss

Should the Meramec Park Lake ultimately be constructed irrespective of the negative impacts on endangered species predicted in this report, then the governmental agencies involved should be required to take actions to help offset the predicted population losses. Many such actions have already been recommended in this report. We believe the most important single area of compensatory activity would be to provide protection to important bat caves on non-project land. This could be done in a number of ways, depending on the attitude of the agencies and private landowners involved.

As mentioned several times previously, the most important single cave in the area is cave 029, on private land. The owners object to all government interference, but would apparently be willing to transfer the cave to a private organization, such as the Nature Conservancy, or possibly to the Missouri Department of Conservation. We recommend that the Nature Conservancy or the Department of Conservation be granted funds to acquire the cave, if necessary, and to gate the entrance. Cave 031, a major *M. sodalis* hibernaculum located near the lake, should be purchased from the private owner, and gated or fenced. Caves 009 and 017, both *M. sodalis* hibernacula on state property, should be gated and/or fenced at the expense of the Army Corps of Engineers. Among caves used by *M. grisescens*, cave 044, now at the edge of a flood easement, should be obtained so that it may be protected when necessary. Cave 054, downstream from the dam, should be purchased from the private owner for the purpose of protection. Cave 058, also downstream from the dam, should be purchased and restored to use by bats. Cave 036 should be purchased from the private owner, and perhaps transferred to the Missouri Conservation Commission, which administers the nearby Indian Trail State Forest. If the Union Dam is constructed, caves 048 and 049 should certainly be acquired and protected.

In the Cave Management Policy of Meramec Park Lake (draft copy, September 1976) the Army Corps of Engineers has suggested the purchase of additional caves in order to "Provide for relocation of forms of cave life from caves to be inundated...." Although we approve of the spirit of this statement, we do not believe that populations of bats in caves to be flooded (primarily *M. grisescens*) can be successfully transported to another cave, a belief supported by M. D. Tuttle (pers. comm.). Instead, we hope that some of the caves formerly used by *M. grisescens* will again be made available to them (as recommended in this report) and that displaced bats will eventually move to these alternate roosts. We have no assurance that they will do so, however.

RECOMMENDATIONS FOR FUTURE STUDIES

Although we have attempted to learn as much as possible about myotine bats in the project area during the short time allotted to us, many questions remain unanswered, some of which relate directly to the proposed lakes; other relate only indirectly to the lakes.

Many of these questions will be the subject of investigation during a three-year study of *Myotis sodalis* by personnel of the Missouri Department of Conservation, scheduled to begin in March 1977.

Much of the emphasis in that study will be on foraging behavior and on summer habitat, wherever it may be found in the state. The question of foraging habitat requirements during "swarming" would be especially important in the Meramec Park Lake area, and will be addressed in the upcoming study, as will the question of actual food habits. Once this is done, we will be in a better position to calculate the amount of M. sodalis habitat lost, as well as the importance of that habitat to the bats.

In respect to the Meramec Park Lake area alone, a number of areas of proposed study have been suggested by our research efforts during the current project. These are simply listed below:

1) Hydrological studies - A ground water hydrologist should determine the impact of the lake and associated developments on ecosystems of bat caves, especially those of M. sodalis hibernacula.
2) Estimate the U. S. population of M. grisescens, thus allowing a better perspective on the effects of the proposed lakes in relation to the entire population of that species.
3) Find out if M. sodalis females are resident and raising their young in portions of the Meramec Basin remote from suitable M. grisescens caves.
4) Find ways to protect important bat caves in the flood pool from inundation in periods of high water.
5) Determine the size of the area surrounding important

bat caves which must be preserved and/or managed to protect the integrity of the cave ecosystem.

6) Monitoring studies:

a) monitor populations of *M. sodalis* and *M. grisescens*.

b) monitor formerly-used caves made available again to the bats to see if the bats recolonize the caves.

c) monitor changes in climate (if any) resulting grom construction of the lakes. These climatological studies should be initiated immediately so that baseline data may be accumulated before the lake is filled.

d) monitor unplanned (private) development so that potential problems can be averted, possibly by zoning areas around important bat caves, foraging habitat, etc.

7) Estimate numbers of gray bats that formerly used caves 006, 008, 058, F15 and Onondaga, and estimate numbers that might use the caves if restored to bat use. This would have to be done by bringing in a consultant, Dr. M. D. Tuttle.

These brief suggestions are intended only as the broadest kind of guidelines; undoubtedly there are other lines of fruitful research not here listed. We suggest that a close liason be maintained among the Corps of Engineers, U. S. Fish and Wildlife Service, and the Missouri Department of Conservation in order to follow up on these suggestions.

Summary

The U. S. Army Corps of Engineers is currently constructing a dam on the Meramec River in eastern Missouri. A second dam is planned for the Bourbeuse River, a major tributary of the Meramec. The resulting Meramec Park Lake and Union Lake will have a negative impact on roosting and foraging habitats of two species of bats protected by a federal law, the Endangered Species Act of 1973. All federal agencies are required by the provisions of the law to protect both individuals and habitat of endangered species within jurisdiction of their projects. In this case the Indiana bat (Myotis sodalis) and the gray bat (Myotis grisescens) have populations of approximately 100,000 and 50,000, respectively, in the area to be impacted by the dams.

An 18-month field study was carried out to determine as much as possible about the ecology of these two species in the project area in order to predict the impact of the dam and to propose management options.

Bats were trapped, netted, and caught by hand. In hibernation they were censused without being subjected to handling. In addition to nets and traps, the following devices and techniques were used: application of colored, numbered plastic bands; quick-reading mercury thermometers; infrared thermometer; motor-driven psychrometer; ultrasonic bat detectors; Cyalume chemiluminescent chemicals; walkie-talkies; Paulin altimeter; and night-viewing device.

Most of the _Myotis sodalis_ hibernate in five major caves in the project area. Smaller numbers, primarily males, spend the summer in the area. During August and September large numbers of adults and young return to the area, preparatory to entering hibernation in October.

Myotis grisescens occupy at least 14 caves in the project area. Some of these are in use from March to November, whereas others are used only as transient caves, maternity caves, or summer male roosts. During the winter _M. grisescens_ is absent from the project area.

Foraging activities of both species were observed by releasing lighted individuals. _Myotis grisescens_ forage over rivers and streams, while most _M. sodalis_ forage over and within hillside and ridgetop forest. Gray bats may move as far as 17 km from roost caves in nightly foraging activities, whereas no lighted Indiana bats were observed more than 2 km from the point of release.

Recaptures of several thousand banded bats demonstrate that the _M. grisescens_ in the project area comprise a single colony that utilizes various caves for different purposes at different times of the year. In the winter, at least one half of them hibernate in two caves in Shannon County, Missouri. _Myotis sodalis_, on the other hand, seem to be divided into five major groups with relatively little interchange among the hibernacula. Not only are few caves suitable for _M. sodalis_ hibernacula, but only certain places within these caves are suitable. In the case of M. grisescens, maternity colonies cannot tolerate any disturbance. Thus both species may suffer mortality involving large segments of their population if certain kinds of disturbance or vandalism occur at these critical caves.

Impacts of the proposed lakes fall into three categories: 1) destruction of foraging habitat by flooding, clearing, development or pollution; 2) destruction of roosting, maternity, swarming, or hibernating caves by flooding, pollution, or other alteration; 3) disturbance of roosting, hibernating, or foraging bats by human activity.

One hundred seventy nine kilometers of M. grisescens foraging habitat (60 percent of all such habitat available to Meramec Park Lake area bats) will be destroyed at flood pool (our calculations). A substantial area of forest used by foraging M. sodalis will be inundated. The inevitable clearing, development, and pollution will add their impact; an examination of Table Rock, Bull Shoals, and Wappapello lakes, among others, affords clear examples of what can be expected at Meramec Park and Union lakes.

Of 19 bat caves judged to be important to one or both of the endangered species, four will be destroyed, eight will suffer severe impacts, four will suffer moderate impacts, two will be only lightly impacted, and the impact on one cannot be projected.

Fortunately, no _M. sodalis_ hibernacula will be flooded, but due to its proximity to the lake, cave 021 will be severely impacted unless elaborate precautions are taken. The other hibernacula will suffer mainly from increased visitation - such excessive visitation has destroyed hibernacula in Kentucky.

In the case of _M. grisescens_, caves 023 and 030 will be destroyed by flood waters. Caves 039 and 044 will be inundated periodically. The others will suffer from increased visitation, which is intolerable in the case of maternity colonies.

Of the 19 important bat caves cited above (one is used by both species), six are on federal land, three are on state land, and ten are on private land. Only one is adequately gated at present (cave 021). For most of the rest we recommend some form of gate, fence, or combination of the two in order to exclude humans. Three _M. sodalis_ hibernacula on government land (caves 009, 017, and 021) have been designated as Critical Habitat under the provisions of the Endangered Species Act. The agencies responsible for these caves are required by law to protect the caves and the bats therein.

Most of the caves located on private land should be leased or purchased with public funds so that they may receive adequate protection. All kinds of development that might result in disturbance, clearing, pollution, road construction, etc. should be kept well away from bat caves.

Caves gated or fenced but used by bats only part of the year could be made accessible to spelunkers during the remainder of the year.

Several caves in the area have probably been used by M. sodalis in the past (including 006, Onondaga, Cathedral and W5). Guano deposits in caves 006, 008, 058, F15, and Onondaga suggest that these caves were once extensively used by M. grisescens. Most of these caves could be restored to bat use if human disturbance was eliminated. If activities to compensate for habitat loss are undertaken it would be wise to concentrate on acquisition and protection of these caves.

In the final analysis, no amount of protection and compensation can eliminate the possibility of a serious impact on one or both of the endangered species if one or both lakes are constructed. We therefore recommend that the lakes not be built. We further recommend that, even if the lakes are not constructed, some agency or agencies undertake the task of acquisition and protection of habitat. Hopefully, such actions will reverse the current precipitous downward trend in population levels of these species.

Acknowledgements

This research was sponsored jointly by the U. S. Army Corps of Engineers, the U. S. Fish and Wildlife Service, and the Missouri Department of Conservation. Thanks are due to T. Baskett and S. Clark who provided invaluable administrative assistance at the University of Missouri. Numerous students and other individuals volunteered their time to assist in field work. J. Werner spent two weeks with us at the beginning of the project to familiarize us with the area and its caves. G. Maupin was instrumental in our March visit to the *M. grisescens* hibernacula. E. Warner provided technical assistance on numerous occasions. Numerous landowners and leasees generously allowed us access to caves and streams on their land. Personnel of the three sponsoring agencies were all very helpful to us, especially J. Brady of the Corps of Engineers, D. Metz of the Fish and Wildlife Service, and K. Sadler of the Department of Conservation. Cave localities and descriptions were made available to us by a wide variety of persons, notably members of the Missouri Speleological Survey. Among these should be singled out D. Rimbach, J. Zollweg, R. Orr, and J. Vineyard. S. Humphrey offered helpful advice during many phases of the study, and joined us in the field for two weeks of concerted effort. This study was carried out under authority of Federal Endangered Species Permit PRT-8-31-C.

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